SANTA CLARA VALLEY WATER DISTRICT

San Jose, California

Groundwater Management in Santa Clara Valley

April 1987

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SANTA CLARA VALLEY WATER DISTRICT

San Jose, California

GROUNDWATER MANAGEMENT IN SANTA CLARA VALLEY

April 1987

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OVERVIEW

SUMMARY

Some 58 percent of all water produced in Santa Clara Valley comes from groundwater. This tremendous subsurface resource, originating from both natural and artificial recharge, requires careful management to protect the quantity and quality of future water supplies. This report evaluates groundwater resources, management practices and alternatives, contamination, and cleanup programs in the Valley. Preparation of this report is part of the Santa Clara Valley Integrated Environmental Management Project, a joint effort of the U.S. Environmental Protection Agency and Santa Clara Valley Water District.

The study area includes Santa Clara, Coyote, and Llagas Subbasins with a total area of over 300 square miles. The geology of Santa Clara Valley is characterized by discontinuous lenses of clay, silt, sand, and gravel. Portions of Santa Clara and Llagas Subbasins contain a lower confined aquifer and an upper unconfined aquifer. The principal recharge in these subbasins occurs in the forebay along elevated basin edges.

Santa Clara Valley, originally developed with an agricultural economy, has been transformed in the past forty years into an intensively urbanized and industrialized area. Water demands are projected to increase from 400,000 AF/year in 1984 to 550,000 AF/year in 2020. Water for the basin originates from local surface water and groundwater plus imported water from state, federal, and City of San Francisco sources. Groundwater management through artificial recharge sustains the yield in Santa Clara Valley and mitigates problems associated with seawater intrusion and land subsidence. Based on imported contracts, sufficient water exists to meet demands to 2020.

Groundwater has been contaminated in localized regions with industrial solvents, gasoline, and agricultural chemicals. More that 100 solvent and 480 gasoline leaks have been reported. As a result some 26 groundwater contamination plumes have been identified and a few public and private wells have been closed. The location of contaminant plumes near existing water supply wells suggests that adverse impacts are possible unless careful monitoring and management practices are followed. Groundwater cleanup has been required at 61 sites. Compliance has been voluntary, but over half the sites are behind schedule.

Current groundwater protection programs are designed to diminish point source releases of contaminants (Hazardous Materials Storage Ordinance and underground tank investigations) and interaquifer transport of contaminants (well sealing program). Supplemental programs suggested in this report include groundwater protection zones, groundwater management zones, and groundwater basin modeling.

The benefits of the groundwater basin are its natural yield, treatment, storage, and conveyance capacities. Several alternatives are considered to replace the groundwater basin; however, they would be several times the cost of current groundwater use if the water were available. The report concludes with recommendations focusing on a basin-wide approach to groundwater management.

RECOMMENDATIONS

In recent years much attention in Santa Clara Valley has been focused on site-specific contamination, and necessarily so, but in the future a broader approach to groundwater concerns also will be required. Many of the following recommendations suggest a basin-wide approach to groundwater management. Matters such as data base management, basin modeling, protection and management zones, and emergency planning require treatment on a unified basis. Much of the District's past successful work has embodied basin-wide management; these recommendations simply amplify and extend that concept.

Geologic Analyses

It is recommended that geologic cross-sections be prepared across zones of contamination, industrial land use areas, and major zones of pumpage.

Cleanup of Soils and Groundwater

It is recommended that groundwater cleanup programs be continued with the coordinated establishment of appropriate cleanup levels and determination of how best to apply the State's non-degradation policy.

Fuel Tank Program

It is recommended that the SCVWD, in cooperation with the San Francisco RWQCB and the Central Coast RWQCB, compile information from individual leaking fuel tank sites and prepare regional site and plume maps. These maps should be used to evaluate the impact of fuel leaks on the basin as a whole.

Underground Tank Storage

It is recommended that the District encourage cities to reach full implementation of their underground tank ordinances by their respective target dates.

Conduit Well Sealing

Given the relatively high concentration of conduit wells near contaminant plumes, it is recommended that the District accelerate the program to complete sealing of all targeted wells. In the future the program should be modified to include areas of contamination as they are discovered.

Well Design Standards

It is recommended that the District work in cooperation with DOHS to assure that all future wells are properly sited, screened, and sealed so that the potential for contamination of potable water supplies is minimized.

Groundwater Quality Monitoring

It is recommended that the District work to establish an enhanced basin-wide groundwater quality monitoring program embracing both mineral and organic analyses.

Water Level Monitoring

It is recommended that the District develop a gradually expanded well monitoring program which will enable individual aquifer levels to be assessed.

Artificial Recharge

It is recommended that the District evaluate the maximum capability of each recharge facility with a view toward future coordinated operation of the facilities to achieve optimal basin management.

Protection Zones

It is recommended that the District study the concept of protection zones and encourage cities and the county to implement land use controls in broad areas where urbanization could adversely impact groundwater resources.

Management Zones

It is recommended that the District recognize the idea of management zones as a means of focusing attention on critical groundwater resources.

Groundwater Basin Modeling

It is recommended that the current effort by SCVWD toward developing a groundwater basin model should be continued with a long term commitment made to maintaining and refining the model.

Data Base Management

It is recommended, that the District evaluate the feasibility of a centralized data base management program for groundwater quantity, quality, and use. The data base system also should embrace the District's current monitoring programs.

Library of Groundwater Information

It is recommended that the District consider establishing an information library related to groundwater so that such materials would be available to interested parties and the general public.

Emergency Planning

It is recommended that the District, in conjunction with the water purveyors, update contingency plans for operation of water sources and water distribution systems under emergency conditions.

SECTION I

INTRODUCTION

BACKGROUND

The Santa Clara Valley Integrated Environmental Management Project (IEMP) is an innovative program of the U.S. Environmental Protection Agency (EPA). It is intended to improve public health protection and environmental management through an integrated approach addressing the problems of hazardous material in the land, air, and water.

The first phase of this project, completed in May 1986, involved evaluation of health risks from toxic pollutants in the environment, including toxic wastes in groundwater associated with Santa Clara Valley's computer industry, other air and water pollutants common to modern urban environments, and excessive nitrates in southern Santa Clara Valley stemming from agricultural practices.

A portion of the second phase of the IEMP is a joint effort of the EPA and Santa Clara Valley Water District. It entails assessment of current water management practices in the Santa Clara Valley, documentation of groundwater quality problems, evaluation of current groundwater quality protection and cleanup programs, and investigation of current water management policies and institutional concerns. This report represents one portion of the second phase effort.

The third phase could involve implementation of recommendations from previous phases of the investigation.

PURPOSE

The purpose of this report is to evaluate groundwater management in Santa Clara County. Included are documentation of groundwater resources, definition of current groundwater management practices, evaluation of contamination problems, and assessment of current groundwater quality protection and cleanup programs. Alternatives for groundwater quality management are described and assessed. This study, conducted for the Santa Clara Valley Water District, provides information and recommendations as part of the Santa Clara Valley IEMP.

SCOPE

This investigation is based primarily on existing information and focuses on current conditions and projections for a planning period to 2020. The study area is the Santa Clara Valley and its underlying groundwater basin, including the Santa Clara, Coyote, and Llagas Subbasins.

ACKNOWLEDGMENTS

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SECTION II

SANTA CLARA VALLEY GROUNDWATER BASIN

GEOGRAPHIC SETTING.

The Santa Clara Valley, located in Santa Clara County, is bordered by San Francisco Bay to the north and by the Pajaro River to the south (Figure II-1). The Diablo Range and the Santa Cruz Mountains flank the valley along the east and west, respectively. The basin is essentially a structural trough lying between the Hayward fault to the east and the San Andreas Fault to the west. The basin topography is subtle, characterized by gentle slopes from the lateral and southern basin edges to the relatively flat basin interior.

The principal surface drainage in the northern portion of the basin occurs through Coyote Creek, which flows out of the Diablo Range into the basin and eventually drains into San Francisco Bay. The southern portion of the valley is drained by tributaries to the Pajaro River, which flows westerly into Monterey Bay.

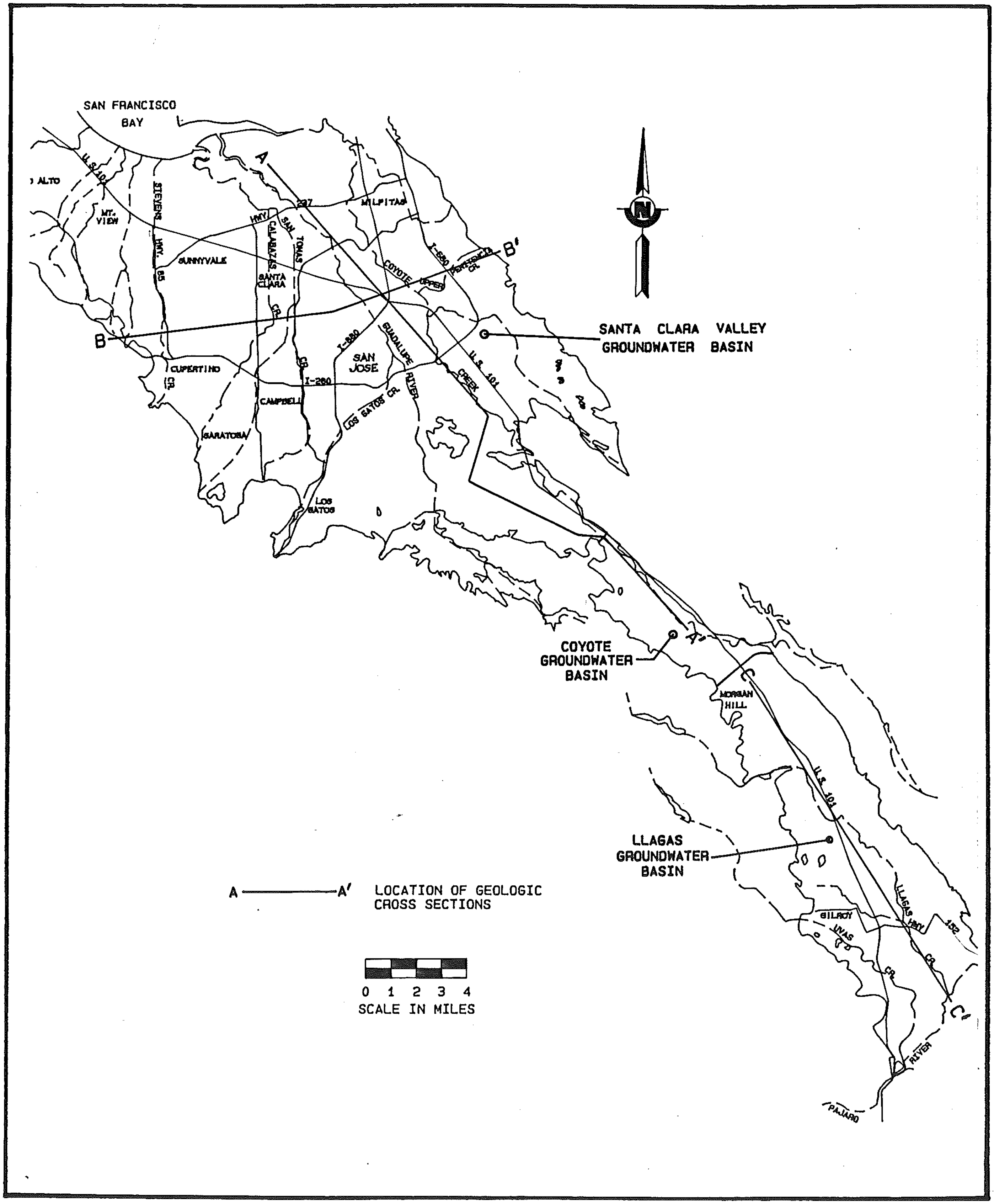
The region is characterized by a Mediterranean climate with distinct wet and dry seasons. The wet season extends from November through April followed by the dry season which extends from May to October. Annual rainfall ranges from 12 inches in the basin interior to over 40 inches in the Santa Cruz mountains (Rantz, 1969).

HYDROGEOLOGY OF SANTA CLARA VALLEY

General Geology. The valley is bounded by marine sedimentary rocks and intrusive rocks dating from the Jurassic to late Tertiary. In general, these formations consist of non-water bearing rocks. Some groundwater occurs in secondary features (fractures, joints, and faults) within these formations, and is generally of good quality except for a slight iron content; however, the deeper groundwater may be saline. Sediments within the valley, which have accumulated over relatively recent geologic time, include water-bearing deposits that now supply thousands of wells with groundwater; therefore, these valley sediments are of primary interest as a water source.

The regional geology immediately south of San Francisco Bay consists of estuarine muds which grade into alluvium to the east, west, and south. The valley is flanked by alluvial fans to the east and west at the base of Diablo Range and Santa Cruz Mountains, respectively.

The estuarine muds, commonly called bay muds, are clays deposited in bay marginal mudflats and tidal salt-water marshes (Helley and LaJoie, 1979). The alluvium was deposited along ancient streams that drained adjacent mountains and meandered through the valley. Stream environments produce a spectrum of deposits ranging from fine grained silts, deposited in flood plains, to coarse gravels, deposited in stream channels and alluvial fans. These deposits have accumulated into a sequence of alluvium that thickens to over 1500 feet in the valley center. Over



Santa Clara Groundwater Basins Surface Drainage and Location of Geologic Cross Sections

Figure II-1

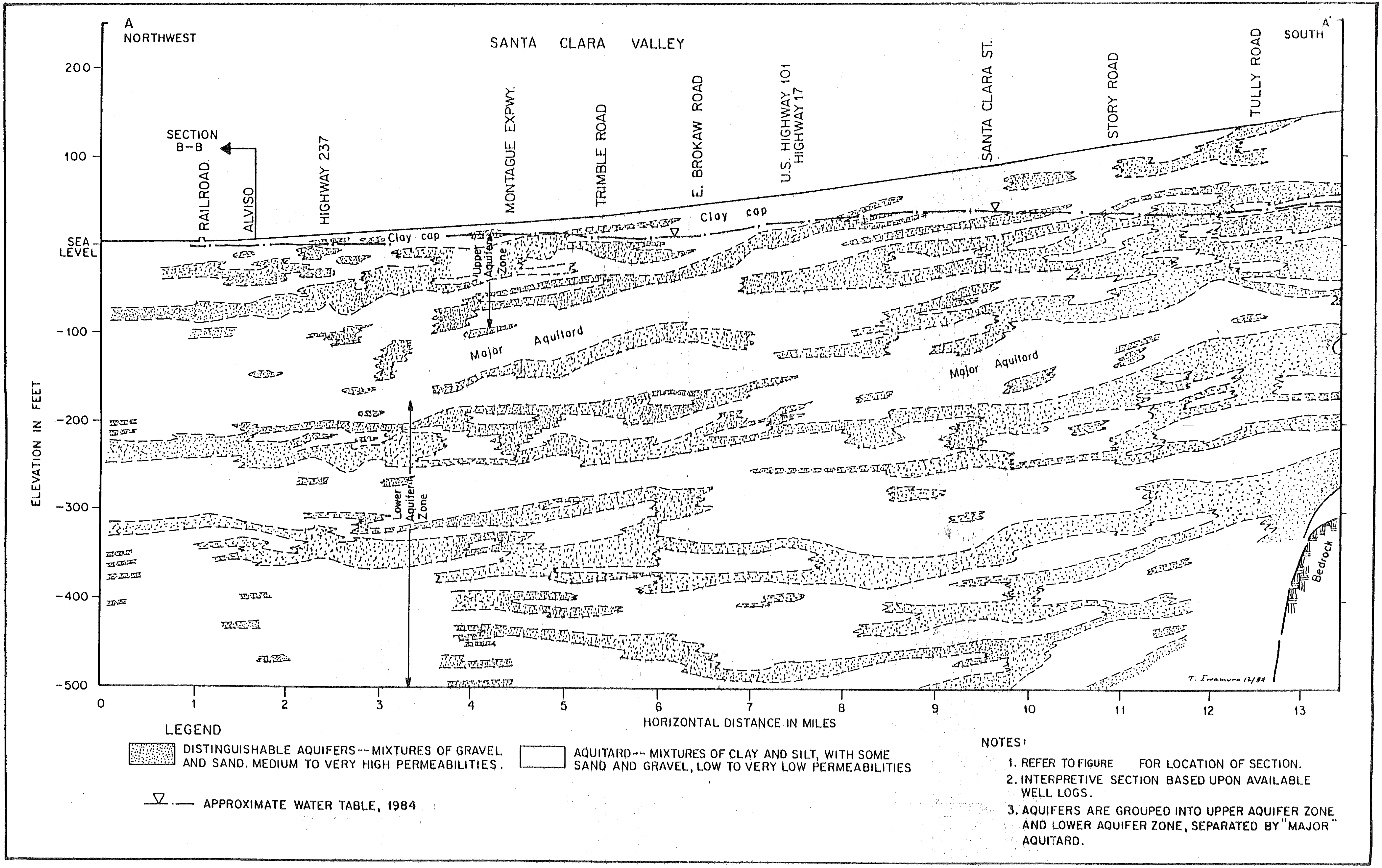
time the alluvium has been eroded and faulted leaving a sequence today that consists of discontinuous lenses of clay, silt, sand and gravel. Some of the finer textured deposits may be marine in origin, deposited during periods of higher sea level (DWR and SCVWD 1975).

Beneath the alluvium in the valley interior, another significant water-bearing unit, the Santa Clara Formation, is present. The formation has been folded and faulted such that it underlies much of the valley. The extent of the formation beneath the alluvium has not been clearly delineated because it is difficult to distinguish it from overlying alluvium in driller's logs. The Santa Clara Formation is also exposed in the hills to the east and west, but is excluded from the groundwater basin as it is non-water bearing. This formation consists of semi-consolidated silt, clay, sand, and gravel.

Previous analyses of the regional geology have relied on interpretation and correlation of available driller's logs. The degree to which these records, generally logged by drillers during emplacement of water wells, reflect the actual geology is difficult to assess in the absence of logs recorded by geologists. Site specific investigations have provided more detailed geologic logs, but these are only available for limited study areas.

Poland (1962) prepared cross-sections in the northern portion of the Santa Clara Basin. Coarse sand and gravel deposits were found along valley margins and in ancient stream channels. Gravel deposits, occurring between 25 and 75 feet below sea level near Alviso, are associated with Guadalupe River. Other significant accumulations of sand and gravel occur along Coyote Creek between San Jose and Edenvale. Poland reports that "none of the deposits can be traced more than a short distance"; therefore, correlations between individual logs were not attempted.

Subsequent investigators have made correlations between logs and interpreted the regional distribution of water-bearing deposits. Figure II-2 shows a cross-section completed by Iwamura (SFRWQCB, 1985). This section shows continuous aquitards (clay and silt) separated by aquifers (sands and gravels) which occur as isolated lenses or thin continuous layers from San Francisco Bay to Edenvale Gap. The major aquitard separates the upper aquifer zone (approximately 0 - 150 feet below mean sea level) from the lower aquifer (greater than 150 feet below mean sea level). South of Edenvale Gap, significant vertically interconnected sand layers are present. The distribution of sediments in the basin reflects the dynamics of stream deposition, whereby coarser deposits were deposited in alluvial fans near the valley perimeter and finer textured materials were deposited in quieter environments in the basin interior (Iwamura, 1980). In Coyote and Llagas Subbasins, the bulk of sediments have been deposited by Coyote Creek as it splayed into the valley at Anderson Dam. This fan axis from Anderson Dam to Morgan Hill forms a groundwater divide between Coyote Subbasin and Llagas Subbasin.



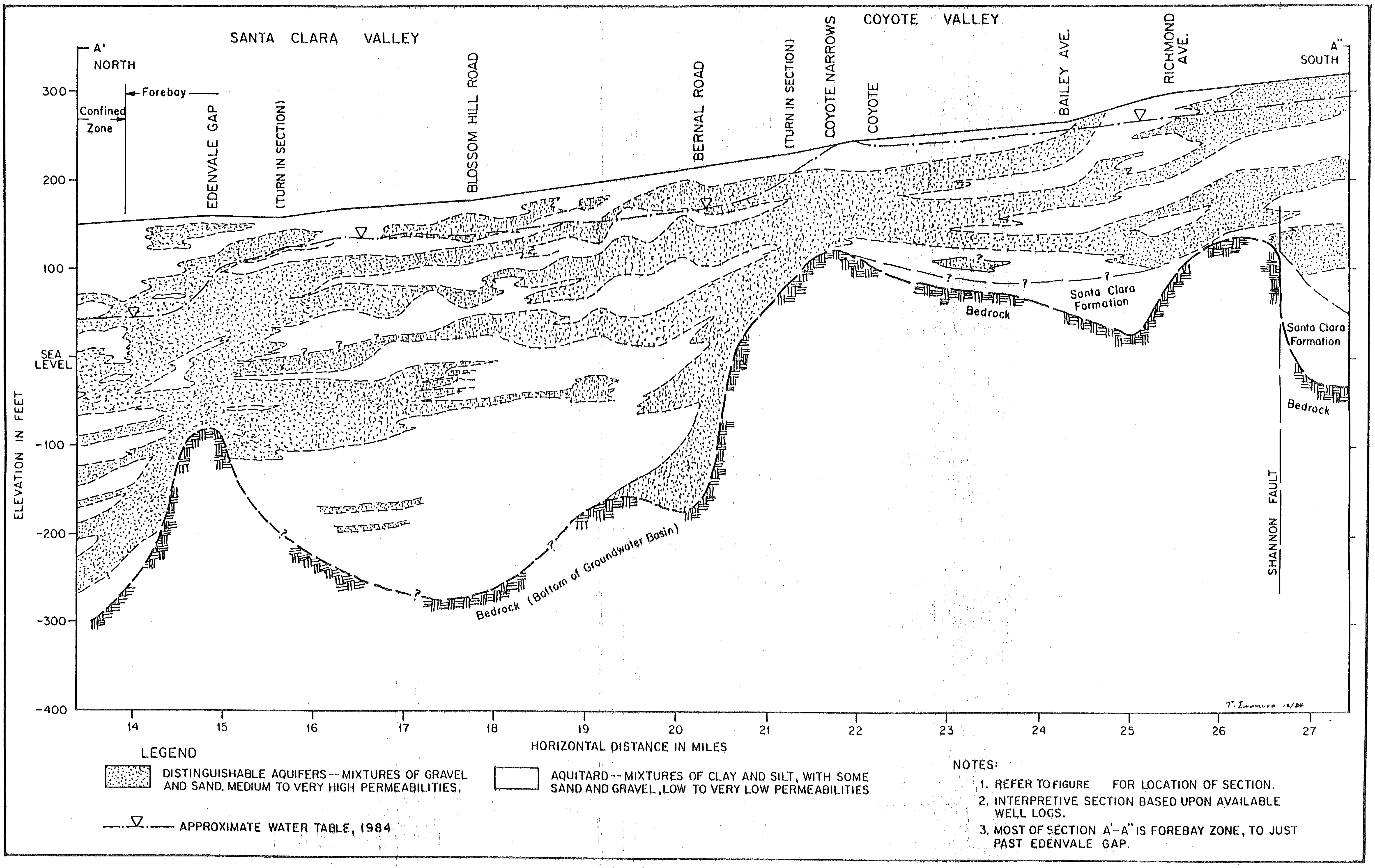
NOTES:

1. REFER TO FIGURE FOR LOCATION OF SECTION.
2. INTERPRETIVE SECTION BASED UPON AVAILABLE WELL LOGS.
3. AQUIFERS ARE GROUPED INTO UPPER AQUIFER ZONE AND LOWER AQUIFER ZONE, SEPARATED BY "MAJOR" AQUITARD.

Interpretive Geologic Section A-A'

(SFRWQCB, 1985)

Figure II-2a


A'
NORTH
SANTA CLARA VALLEY
COYOTE VALLEY
A''
SOUTH
Forebay
Confined Zone
EDENVALE GAP
(TURN IN SECTION)
BLOSSOM HILL ROAD
BERNAL ROAD
(TURN IN SECTION)
COYOTE NARROWS
COYOTE
BAILEY AVE.
RICHMOND AVE.
300
200
100
SEA LEVEL
-100
-200
-300
-400
ELEVATION IN FEET
Santa Clara Formation
Bedrock
Santa Clara Formation
Bedrock
Bedrock (Bottom of Groundwater Basin)
SHANNON FAULT
?
T. Iwamura 12/84
14
15
16
17
18
19
20
21
22
23
24
25
26
27
HORIZONTAL DISTANCE IN MILES
LEGEND
DISTINGUISHABLE AQUIFERS -- MIXTURES OF GRAVEL AND SAND, MEDIUM TO VERY HIGH PERMEABILITIES.
AQUITARD -- MIXTURES OF CLAY AND SILT, WITH SOME SAND AND GRAVEL, LOW TO VERY LOW PERMEABILITIES
APPROXIMATE WATER TABLE, 1984
NOTES:
1. REFER TO FIGURE FOR LOCATION OF SECTION.
2. INTERPRETIVE SECTION BASED UPON AVAILABLE WELL LOGS.
3. MOST OF SECTION A'-A'' IS FOREBAY ZONE, TO JUST PAST EDENVALE GAP.

Interpretive Geologic Section A'-A''
(SFRWQCB, 1985)

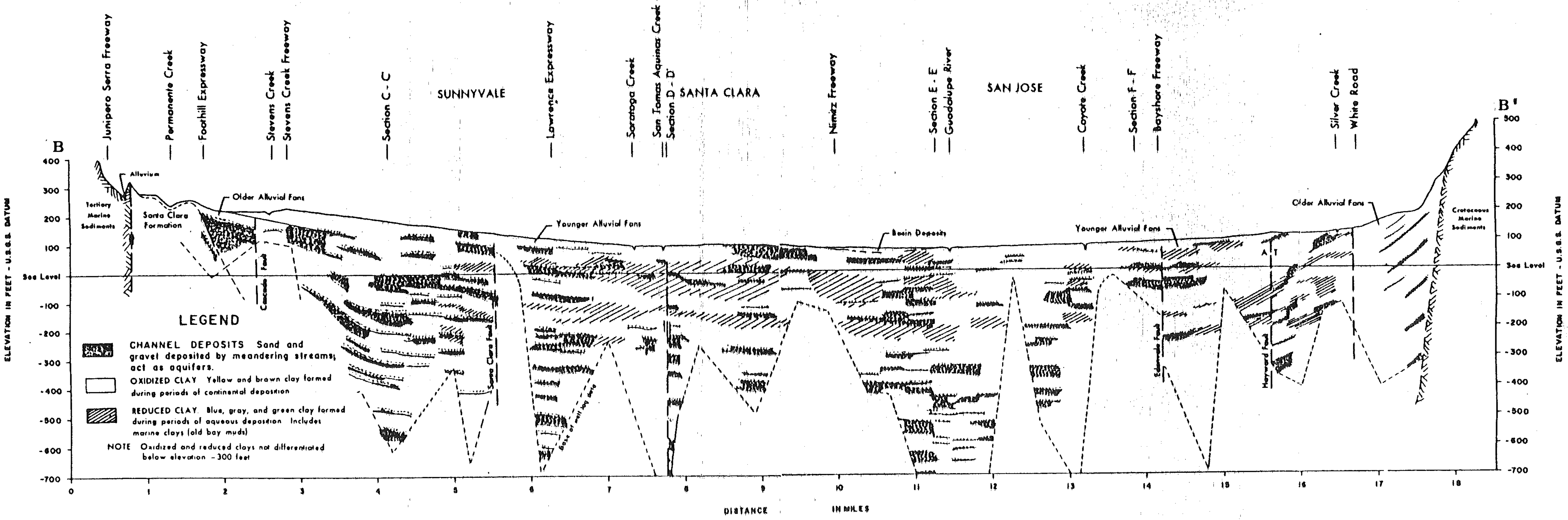
Figure II-2b

The Department of Water Resources (1975 and 1981) has also made regional correlations of the geology throughout the basin. They employed a program, GEOLOG, to extract information from driller's logs to develop regional cross-sections and discrete ten-foot interval subsurface maps. This tool enabled the processing of a considerable amount of data and the identification of major stream channel deposits and faults. Figure II-3 illustrates a generalized geologic cross-section across Santa Clara Valley. In the basin interior thick beds of clay deposits with scattered sand layers are present. Figure II-4 depicts a composite of the discrete interval maps from 50 to 100 feet below mean sea level. Faults were found to begin at about 50 feet below mean sea level, leading to the conclusion that the valley was "compartmentalized with respect to ground water movement." Many channel deposits have been identified including those associated with ancient Coyote Creek, Guadalupe River, and Stevens Creek channels.

Figure II-5 shows a generalized geologic cross-section for the southern portion of Santa Clara Valley. In addition to alluvial deposits, lacustrine (lake) deposits are present in southern portions of the basin. Lake San Benito sediments occur below an approximate elevation of 295 feet, and extend laterally beyond the Pajaro River in the south to just south of Morgan Hill in the north. Lake San Juan was younger than Lake San Benito and its sediments accumulated over Lake Benito clays south of Gilroy at elevations below about 195 feet. The lake deposits become progressively thicker south of the Pajaro River, reaching a maximum thickness of over 265 feet.

Soils. Soils in the Santa Clara Valley, mapped at the association level, are depicted on Figure II-6. The associations have been categorized into five groups based on their drainage and genetic characteristics. The valley is dominated by soils in groups II and III. Group III soils are moderately to somewhat excessively well drained and medium to fine textured alluvial plain and fan soils. Group II soils have developed over finer textured materials and are somewhat poor to poorly drained. These soils are present primarily in the basin interior south of San Francisco Bay. In addition, group II soils are found flanking western portions of the basin south of Oak Hill and south of Gilroy.

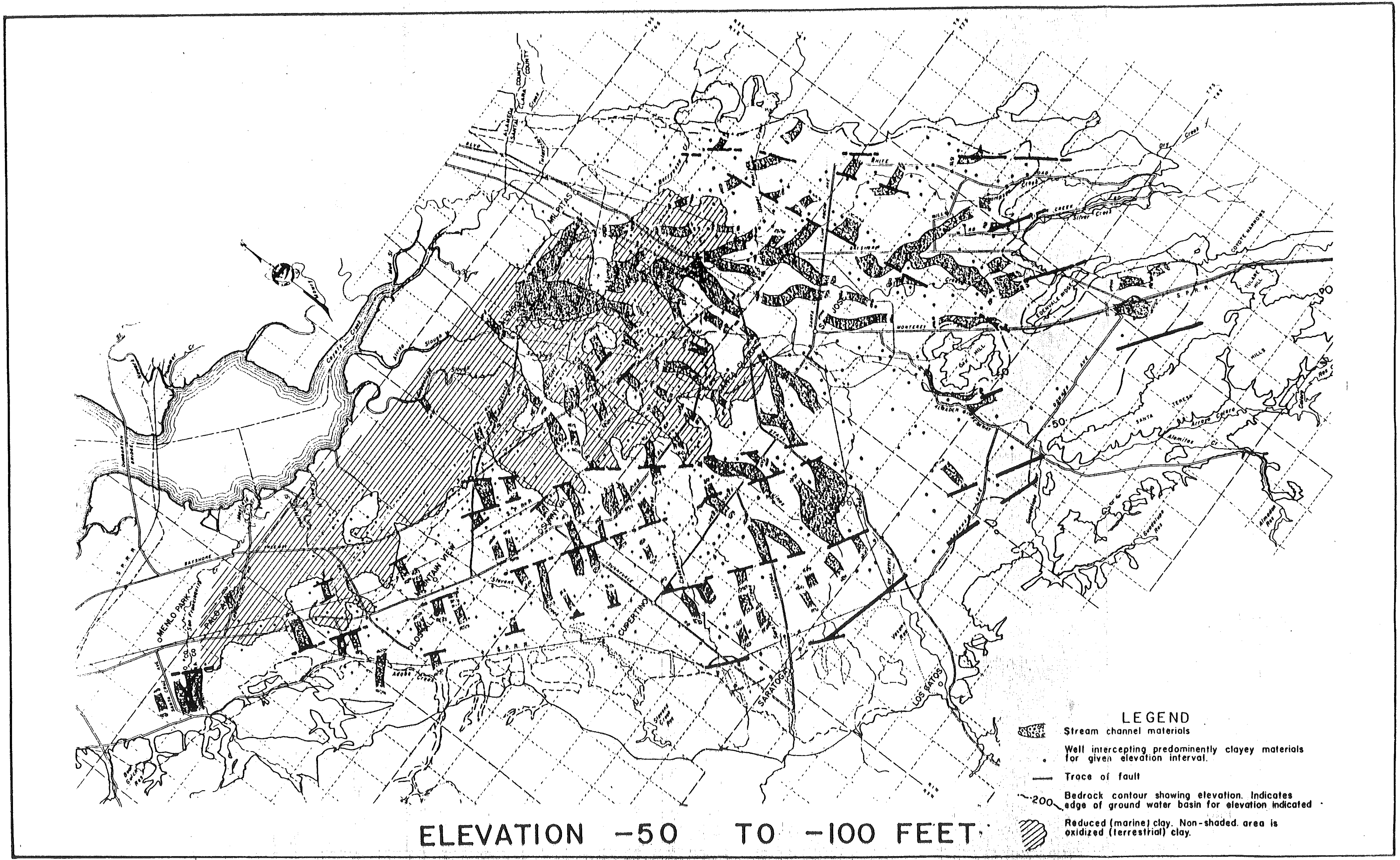
Hydrology of the Groundwater Subbasins. Groundwater basins are defined as hydrogeologic units containing one large aquifer or several connected and interrelated aquifers. Basins are often divided into subbasins based on the presence of features that naturally separate them. The Santa Clara Basin has been subdivided into three subbasins: the Santa Clara, Coyote, and Llagas (Figure II-1). A prominent bedrock constriction in the valley at Coyote Narrows separates the Santa Clara Subbasin from the Coyote Subbasin. The southern extent of the Coyote Subbasin is defined by a topographic divide, which separates it from the



Note: Refer to Figure II-1
for location of section.

Interpretive Geologic Section B-B'
(DWR, 1975)

Figure II-3

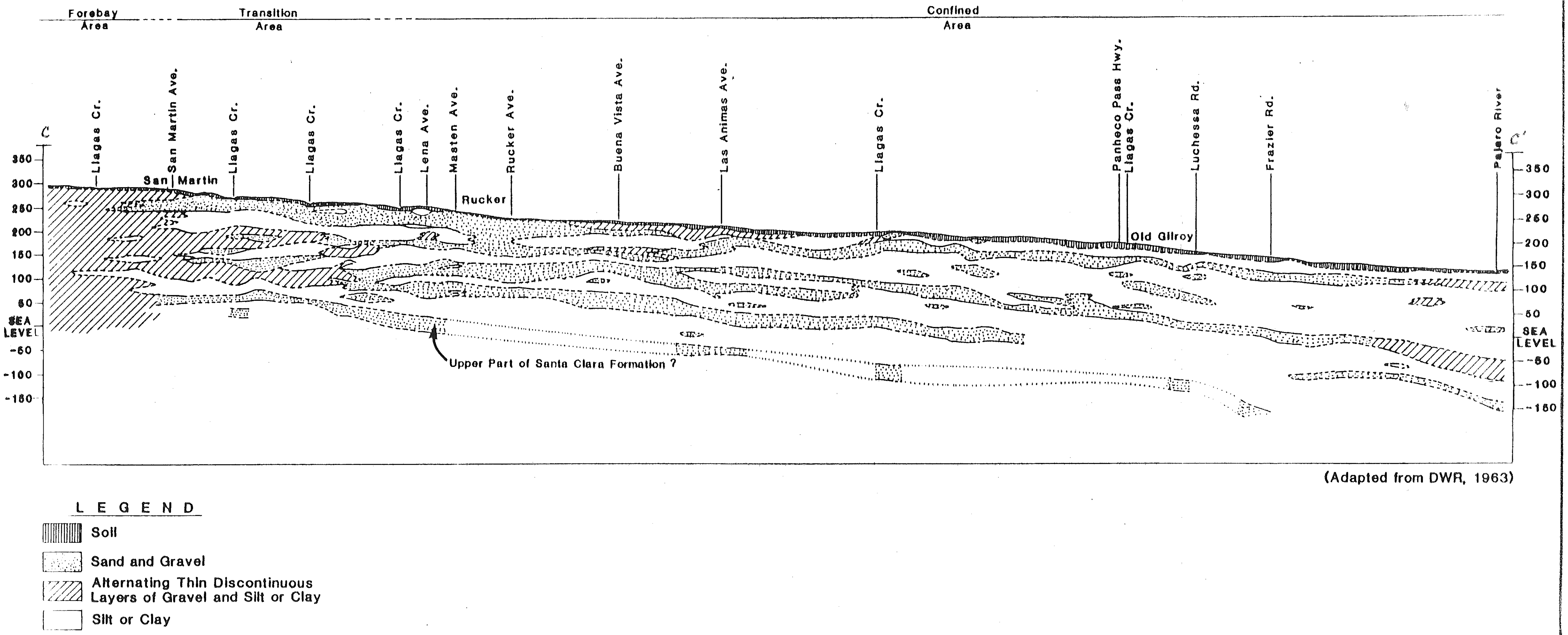


Subsurface Deposition, Santa Clara Valley
(DWR, 1975)

Figure II-4

Generalized Geologic Cross-Section

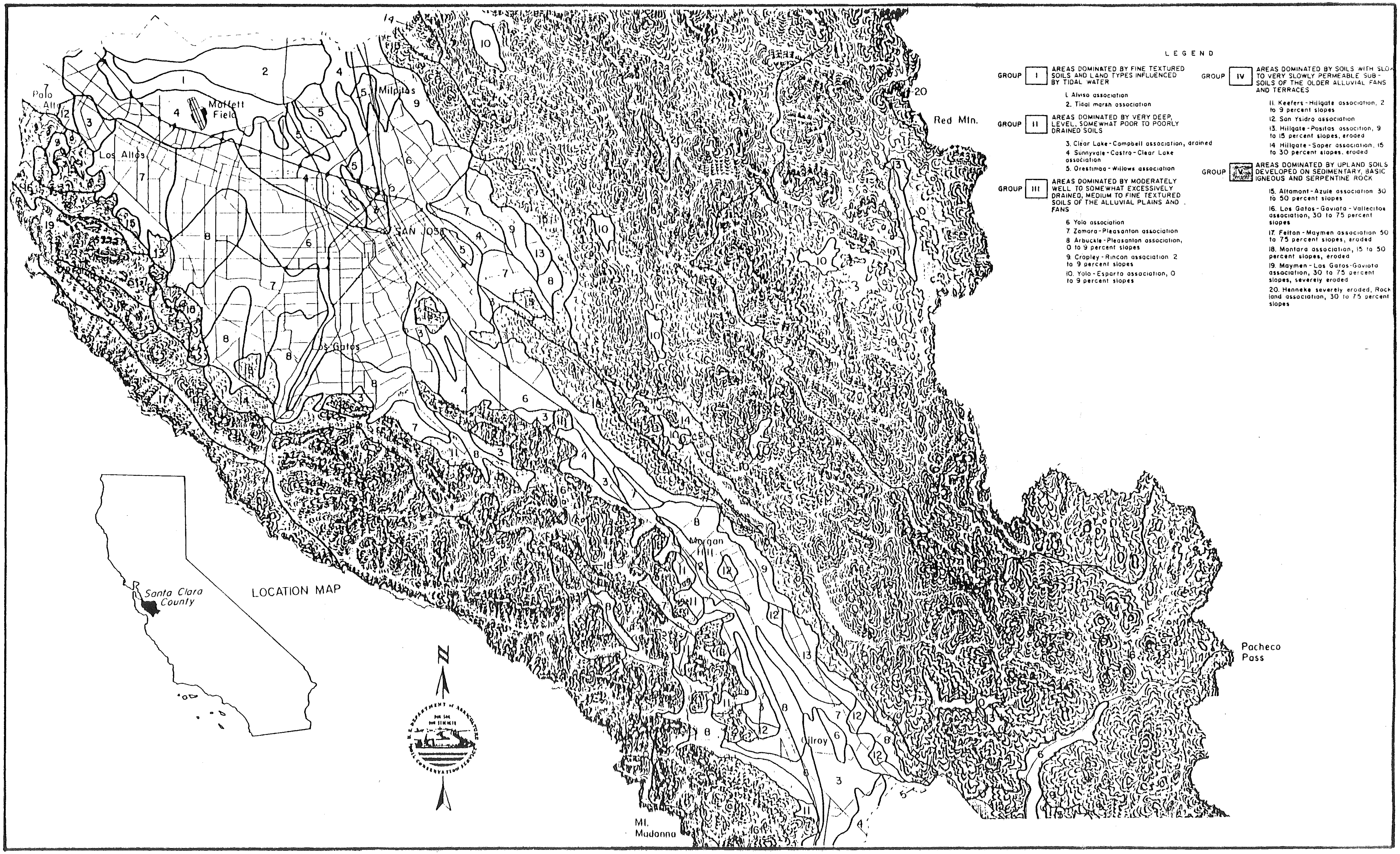
San Martin to Pajaro River



(Adapted from DWR, 1963)

Interpretive Geologic Section C-C'
(Luhdorff and Scalmanini, 1986)

Figure II-5


LEGEND
GROUP I AREAS DOMINATED BY FINE TEXTURED SOILS AND LAND TYPES INFLUENCED BY TIDAL WATER
1. Alviso association
2. Tidal marsh association
GROUP II AREAS DOMINATED BY VERY DEEP, LEVEL, SOMEWHAT POOR TO POORLY DRAINED SOILS
3. Clear Lake-Campbell association, drained
4 Sunnyvale-Castro-Clear Lake association
5. Orestimba-Willows association
GROUP III AREAS DOMINATED BY MODERATELY WELL TO SOMEWHAT EXCESSIVELY DRAINED, MEDIUM TO FINE TEXTURED SOILS OF THE ALLUVIAL PLAINS AND FANS
6 Yolo association
7 Zamora-Pleasanton association
8 Arbuckle-Pleasanton association, 0 to 9 percent slopes
9 Cropley-Rincon association 2 to 9 percent slopes
10. Yolo-Esparto association, 0 to 9 percent slopes
GROUP IV AREAS DOMINATED BY SOILS WITH SLO TO VERY SLOWLY PERMEABLE SUB-SOILS OF THE OLDER ALLUVIAL FANS AND TERRACES
11. Keefers-Hillgate association, 2 to 9 percent slopes
12 San Ysidro association
13. Hillgate-Positas association, 9 to 15 percent slopes, eroded
14 Hillgate-Soper association, 15 to 30 percent slopes, eroded
GROUP V AREAS DOMINATED BY UPLAND SOILS DEVELOPED ON SEDIMENTARY, BASIC IGNEOUS AND SERPENTINE ROCK
15. Altamont-Azule association 30 to 50 percent slopes
16. Los Gatos-Gaviota-Vallecitos association, 30 to 75 percent slopes
17. Felton-Maymen association 50 to 75 percent slopes, eroded
18. Montara association, 15 to 50 percent slopes, eroded
19. Maymen-Los Gatos-Gaviota association, 30 to 75 percent slopes, severely eroded
20. Henneke severely eroded, Rock land association, 30 to 75 percent slopes
Palo Alto
Moffett Field
Milpitas
Los Altos
SAN JOSE
Los Gatos
Red Mtn.
Morgan Hill
Gilroy
Mt. Madonna
Pacheco Pass
Santa Clara County
LOCATION MAP
N

Soil Groups in Santa Clara County
(SCS, 1968)

Figure II-6

Llagas Subbasin. The Pajaro River delineates the southern extent of the study area.

Santa Clara and Llagas Subbasins share common hydrologic features. The principal recharge occurs in the forebay zone, located along the elevated edges of the subbasins. The forebay consists of unconfined, permeable alluvium separated by finer textured materials. Coyote Subbasin is basically unconfined with recharge taking place throughout the subbasin. Mechanisms of recharge in the subbasins include infiltration from streams, excess irrigation waters (balance after evapotranspiration), rainfall, and artificial recharge.

In the forebay of Santa Clara and Llagas Subbasins, lenses of sand and gravel are the principal aquifers, separated by finer textured materials that form discontinuous or leaky aquitards. In the basin interior of the Santa Clara Subbasin, water table conditions are present in the shallow aquifer zone (approximately 10-150 feet below mean sea level), while artesian conditions are present in the deep aquifer greater than 150 feet). Confined conditions are also present in southernmost Llagas Subbasin where thick clay layers are present. Figure II-7 shows the location of confined zones in Santa Clara Valley.

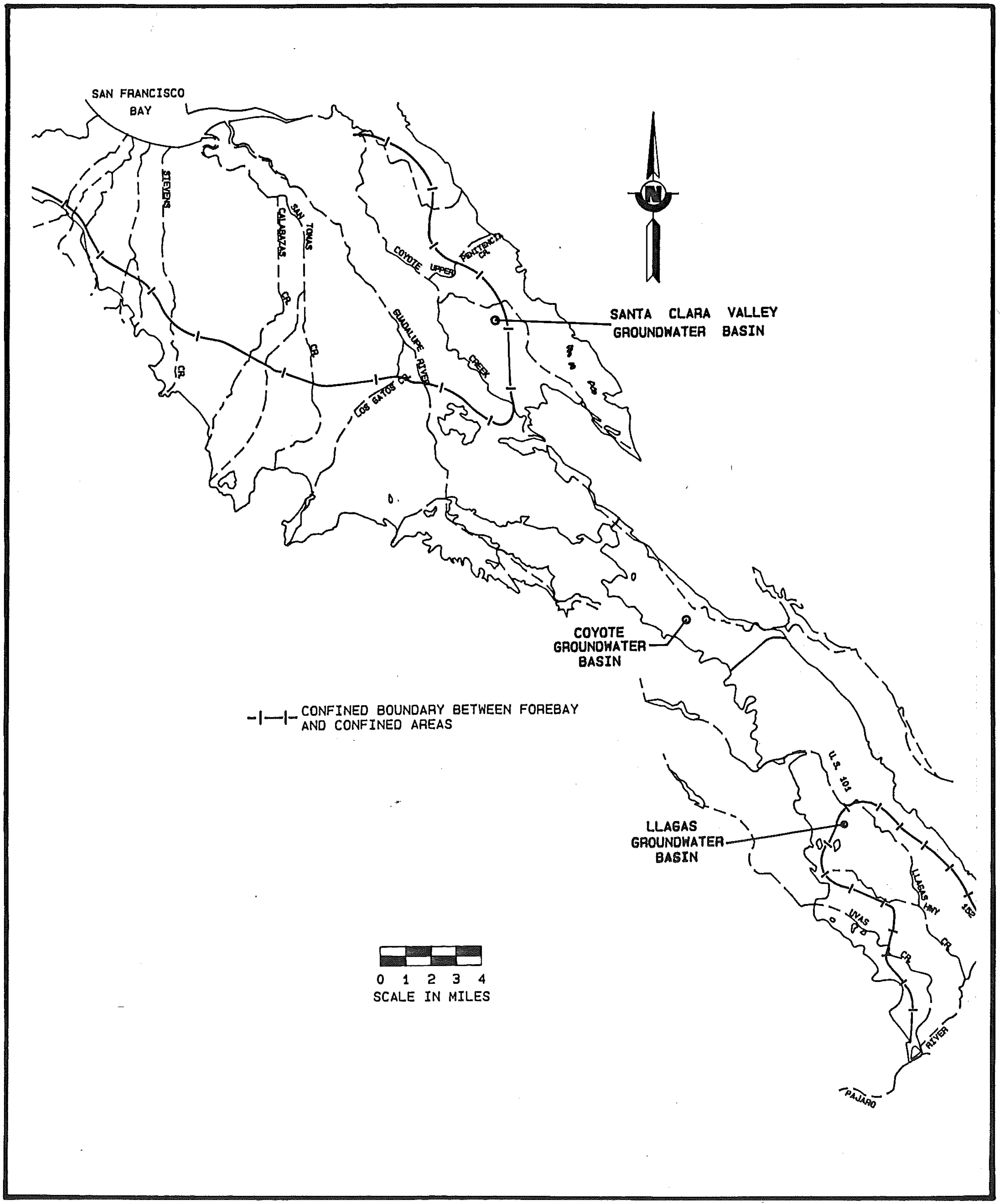
Aquifer transmissivity data are scattered so that it is difficult to generalize aquifer properties for the entire basin. Transmissivities are generally high in the forebay. Pump tests, conducted in wells operated by Great Oaks Water

Company, indicate transmissivities ranging from 72,000 to 650,000 gpd/ft in wells screened at multiple intervals. These results are summarized on Table II-1.

Table II-1.
Aquifer Properties in the Forebay,
Santa Clara Subbasin.

WELL NO.	DISCHARGE (gpm)	HEAD CHANGE (ft)	SPECIFIC CAPACITY (gpm/ft)	TRANSMISSIVITY* (gpd/ft)
1	1068	6.5	164.3	329,000
3	1043	7.9	132.0	264,000
4	1679	18.	93.3	187,000
7	1361	32.	42.5	85,000
9	970	3.0	323.3	647,000
10	1205	7.4	162.8	326,000
11	1158	6.3	183.8	368,000
12	1221	3.5	348.8	698,000
15	1444	5.2	277.6	555,000
16	1844	28.7	64.2	128,000
18	2108	58.3	36.1	72,000

Source: Pacific Gas and Electric Company, Pump Test Reports, courtesy of Great Oaks Water Company.
*Transmissivity = (2000 x Specific Capacity)



Confined Zones in Santa Clara and Llagas Subbasins

Figures II-7

Measurements of vertical permeabilities generally have not been established for the valley deposits. Prior to the occurrence of heavy pumping in the basin, many wells in the confined zone were flowing; this is indicative of an upward gradient. However, pumping patterns have modified this gradient. A leaky aquifer test performed near Palo Alto (Sheahan, 1977) detected a measurable vertical permeability in the shallow aquifer system. Tests in the deep aquifer revealed that there is complete hydraulic separation between the shallow and deep aquifers. However, wells that are poorly constructed or abandoned provide a connection between shallow and deep aquifers in this area (Iwamura, 1980).

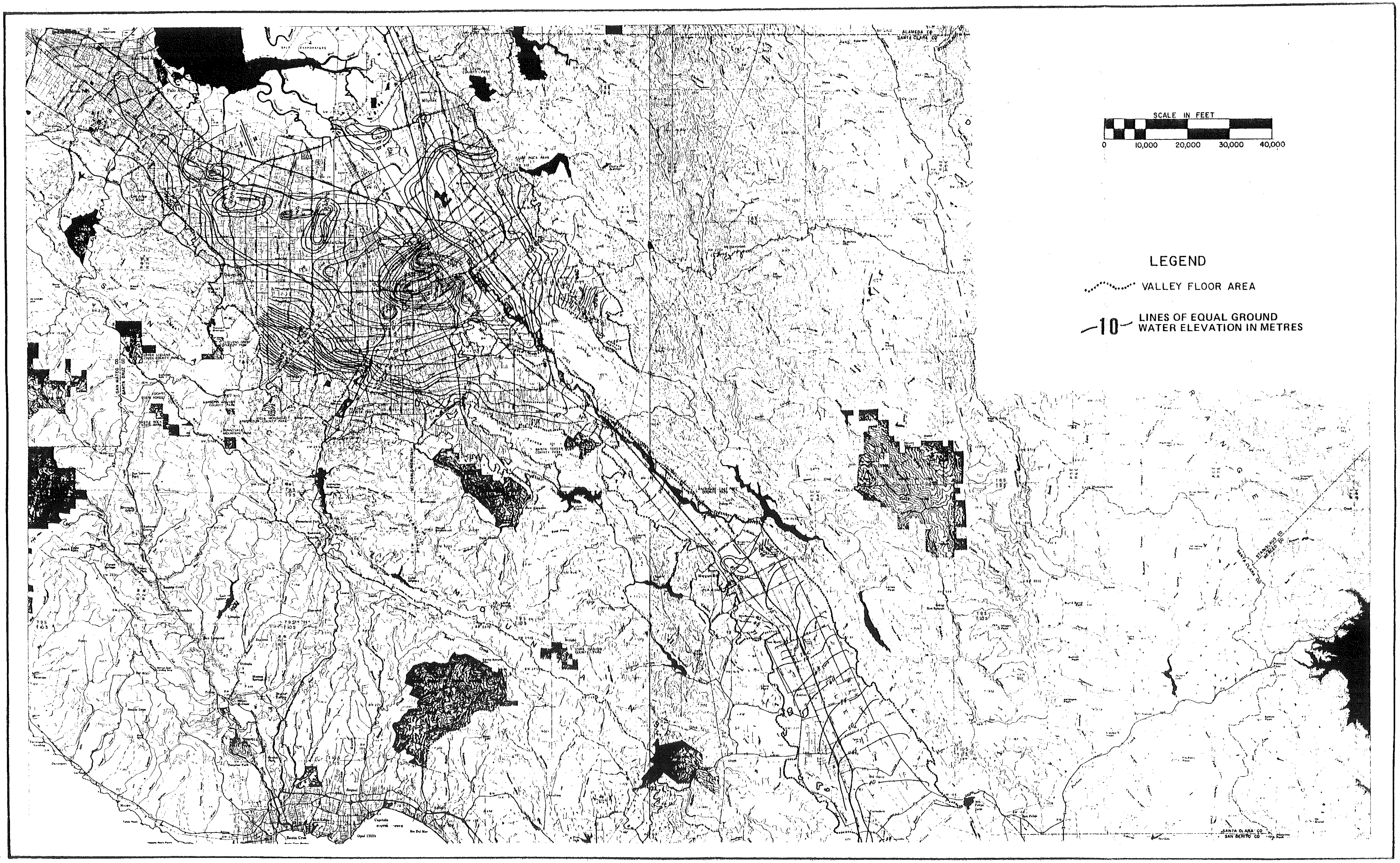
The lack of a natural hydrogeologic connection is fairly well established from work conducted in Palo Alto and generally is true throughout the confined zone. However, this situation may not occur everywhere within the confined region given the complex alluvial sequence.

Santa Clara Subbasin Hydrogeology. The Santa Clara Subbasin is the largest of the three subbasins, covering 225 square miles (SFRWQCB, 1985). With groundwater levels approaching ground surface in many areas, the subbasin contains an estimated 3,225,000 acre feet of water between depths of 10 and 310 feet. The estimated natural groundwater yield in the basin, which includes precipitation, irrigation return-flows, runoff from minor streams, and subsurface inflow, is 58,200 acre feet per year (SCVWD, May 1981).

Regional flow in this subbasin is from the peripheral recharge zone known as the forebay, which flanks the subbasin on the east and west, toward the center of the subbasin, and continuing north to discharge into San Francisco Bay. Additional recharge water is supplied from the Coyote Valley Subbasin through Coyote Narrows and also from nonwater-bearing formations adjacent to the subbasin. Historically flowing artesian wells were present in the interior portion of the basin. Since 1975, some wells have flowed intermittently.

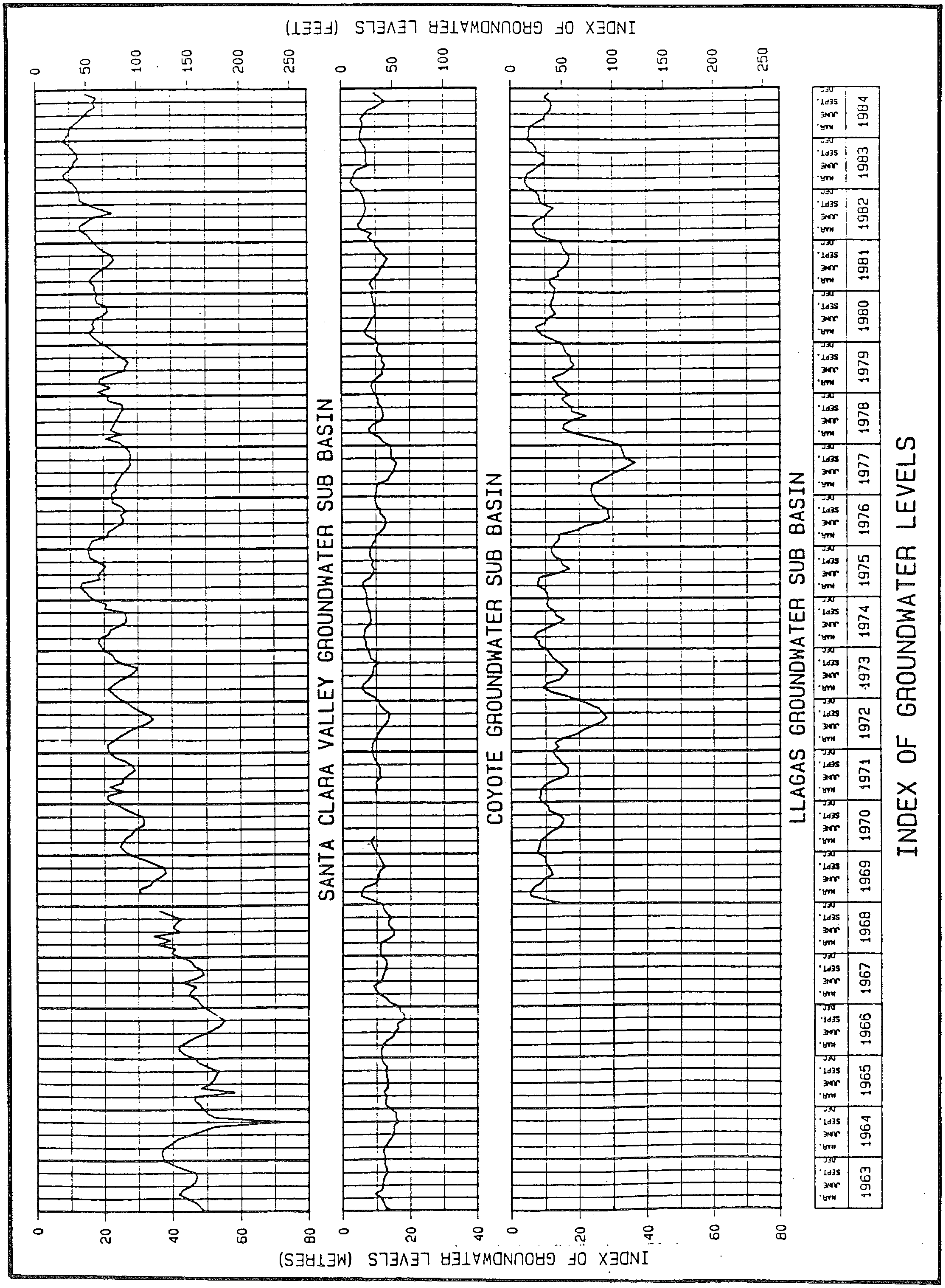
Figure II-8 illustrates groundwater level contours in the entire basin. This map is based on water levels measured in more than 350 wells. The regional direction of groundwater flow in Santa Clara Subbasin from the elevated edges of the basin toward San Francisco Bay is modified in the vicinity of heavy groundwater withdrawals. Significant cones of depression surround pumping wells in Mountain View, San Jose, and Alviso.

The upper curve in Figure II-9 illustrates a graph of groundwater levels over a 21 year period in Santa Clara Subbasin. The hydrograph data were collected from an individual well selected to represent general trends in water levels in the subbasin. On a yearly basis fluctuation of groundwater levels reflects seasonal precipitation patterns. Water levels increase during wet months (November through March) and decline during dry months (April through September).



Lines of Equal Groundwater Elevation
October 1, 1984
(District, 1985)

Figure II-8



Groundwater Levels, 1963-1984
(District, 1985)

Figure II-9

Groundwater levels in Santa Clara Subbasin have risen since 1965, the year marking the first delivery of imported water via the South Bay Aqueduct. During the ten year period, 1974 to 1984, high and low groundwater elevations spanned over 60 feet according to the hydrograph in Figure II-9. Water levels were relatively low during the 1975 - 1977 drought. However, the drought had little long-term effect, and water levels gradually rose during subsequent wet years.

Groundwater in the central Santa Clara Subbasin occurs in distinct upper and lower aquifers. The upper unconfined aquifer is generally found at depths less than 150 feet. Lenses of sand and gravel form the principal aquifer and are separated by finer textured materials that form discontinuous or leaky aquitards. The lower zone contains an aquifer that is generally under confined (artesian) conditions. The lower aquifer is similar in character to the shallow zone; however, intervening silt and clay layers act effectively as aquitards.

Most pumpage from large-capacity wells in the Santa Clara Subbasin is from the lower aquifer. However, some individual domestic wells tap only the upper aquifer, while some large-capacity wells tap both the upper and lower aquifers.

Coyote Subbasin Hydrogeology. The Coyote Subbasin covers 15 square miles and has an estimated storage capacity of 76,000 acre-feet (SFRWQCB, 1985). The long-term average natural yield of the subbasin has been estimated to be 4,400 acre feet per year (SCVWD, 1981). Within the Coyote Subbasin, the direction of regional groundwater flow is toward the northwest (Figure II-8). Groundwater discharges into Coyote Creek as it nears Coyote Narrows. The water table rises in the Narrows because of the narrow width and rise in elevation of the basin floor.

Historic changes in this subbasin's water levels have been more subdued than those occurring in the Santa Clara Subbasin. During 1974 through 1984, water levels in an index well fluctuated over a 40 - foot span, as can be seen in the second curve of Figure II - 9.

In Coyote Subbasin groundwater occurs under mostly unconfined conditions with some localized areas of confinement. The principal natural recharge in this subbasin occurs by direct percolation through the Coyote Creek streambed. The amount of water in this creek is controlled by releases from Anderson Reservoir and use of Coyote Canal. In addition, lesser amounts of recharge water are supplied by tributaries of Coyote Creek, irrigation return flows, rainfall, and subsurface contributions from nonwater-bearing formations along the sides of the subbasin.

Maximum thickness of the alluvial aquifer ranges from 500 feet in the south to 150 feet at the Coyote Narrows.

Llagas Subbasin Hydrogeology. The Llagas Subbasin covers 74 square miles with a storage capacity of 475,000 acre-feet (SCVWD, 1975). Estimated long-term average natural groundwater yield for this subbasin is 45,200 acre-feet/year

(SCVWD, 1981) Regional groundwater flow is southward toward the Pajaro River (see Figure II-8). Groundwater recharge in this subbasin occurs along upper reaches of Llagas and Uvas creeks, which enter the subbasin on the west side. Indirect recharge from Coyote Creek may occur as creek water infiltrates and moves laterally into the northern end of the subbasin. In general this subbasin possesses a relatively low natural recharge capability (DWR and SCVWD, 1981).

Between 1972 and 1984, fluctuations in groundwater levels were more extreme than in either the Coyote or Santa Clara Subbasins (Figure II-9) due to greater proportionate draft on the basin for its size and inconsistent recharge flows. During the 1975 - 1977 drought, groundwater levels dropped nearly 70 feet from levels recorded in the previous two years. Overall, levels fluctuated more than 100 feet between 1974 and 1984 (see Figure II-9). However, this fluctuation has occurred on a seasonal basis and is not indicative of a long-term trend.

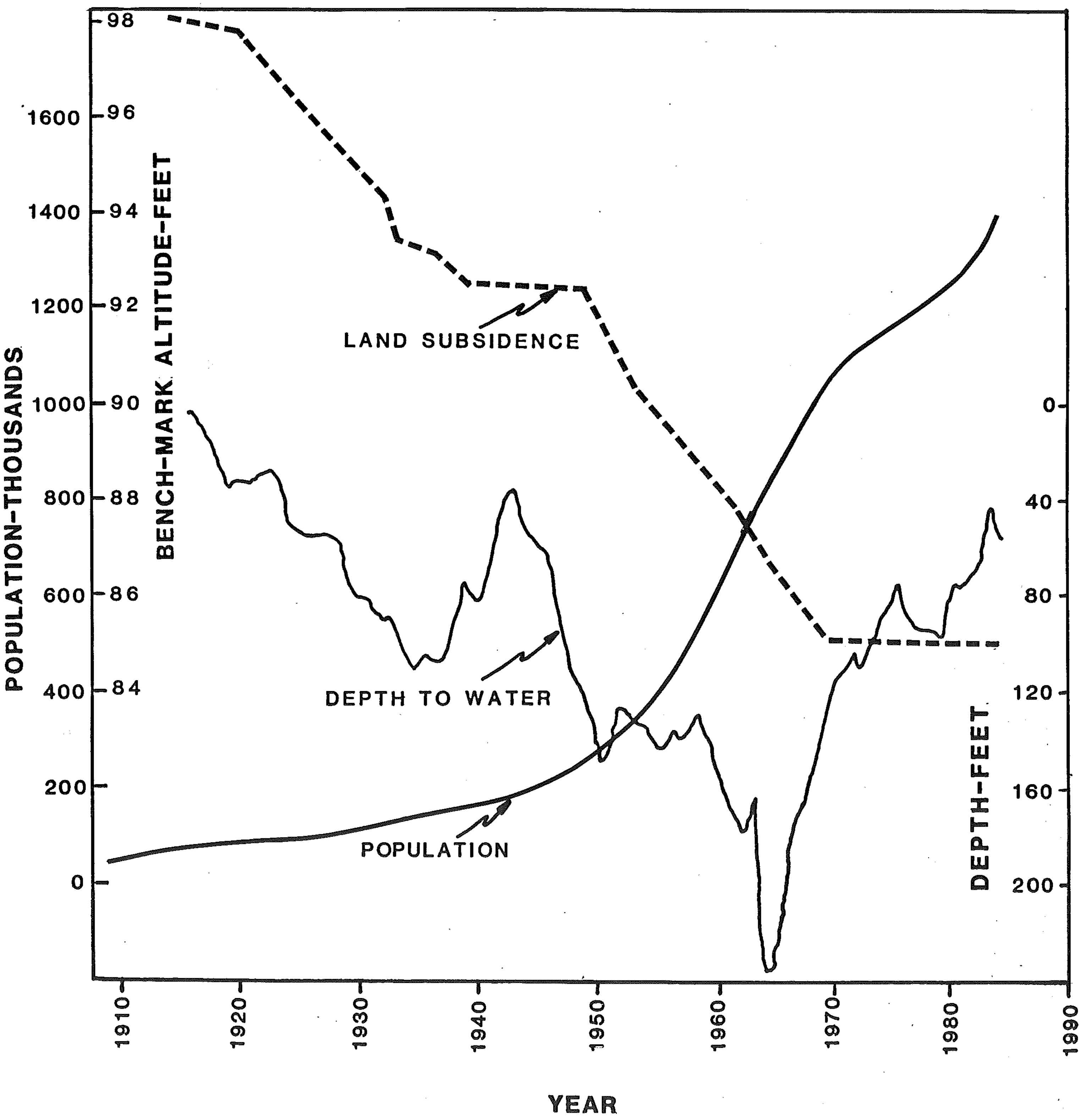
Groundwater exists under both confined and unconfined conditions. Between Morgan Hill and Gilroy there are zones of confinement due to the presence of clays in the southern half of the basin (Figure II-5). The clay thickens to the southeast creating confined conditions extending from Old Gilroy to San Benito County. Historically, many of the wells is this area were artesian; however, extensive pumpage has subsequently reduced the head. Presently some wells in this area are artesian on an intermittent basis.

SECTION III

WATER DEMAND

The Santa Clara Valley, originally developed with an agricultural economy, has been transformed in the past forty years into an intensively urbanized and industrialized area. The population of the valley has grown rapidly to its current level of about 1.4 million. Most of this population is concentrated in the northern part of the valley, which is also an internationally-known center for the electronics and computer industry. In contrast, the southern Santa Clara Valley has retained an agriculturally based economy, with a sparser rural population and two major communities, Morgan Hill and Gilroy.

Concomitantly, water demand and use has changed significantly. In the northern Santa Clara Valley, agricultural groundwater demands in the 1900's gradually led to overpumpage (Figure III-1). The need for artificial recharge was recognized in the 1930's; this led to the construction of local reservoirs and recharge facilities, causing groundwater levels to rise after 1935. With the influx of population during and after World War II, municipal and industrial demands for potable water increased substantially and water levels fell sharply. Overdraft occurred again until after 1965, when South Bay Aqueduct water was first imported. In south Santa Clara County, both municipal and agricultural water demands have increased gradually.



Historical Population, Depth to Water and Land Subsidence in Santa Clara County 1910-1984

Figure III-1

POPULATION

As indicated in Figure III-1, the population of Santa Clara began to increase significantly in the 1940s and 1950s, and grew at a rapid rate from 1955. This growth has been accompanied by an increase in water demand.

As discussed in the District's 1975 Master Plan, the County Planning Department has based its projections on a number of assumptions. First, the natural growth of the county is assumed to approximate zero population growth (2.1 births per family). In addition, to account for net inmigration, the County assumed that new residents will move into the county at rates of 5,000, 10,000, or 15,000 persons per year. Using these assumptions, the County prepared three projections to the year 2000: the reasonable low, expected average, and reasonable high population projections. All three projections, plus a projection assuming no inmigration, are depicted in Figure III-2.

LAND USE

Current land use in Santa Clara and Coyote Subbasins is shown in Figure III-3 (SFRWQCB, July 1985). Land use categories used in constructing this map include residential, light industrial, commercial, open space, and miscellaneous. As indicated, the central portion of the northern valley is predominantly residential. Industrial areas are clustered along the major highways, particularly in the north. Open land occurs primarily along the margins of San Francisco Bay, along the foothills, and to the south.

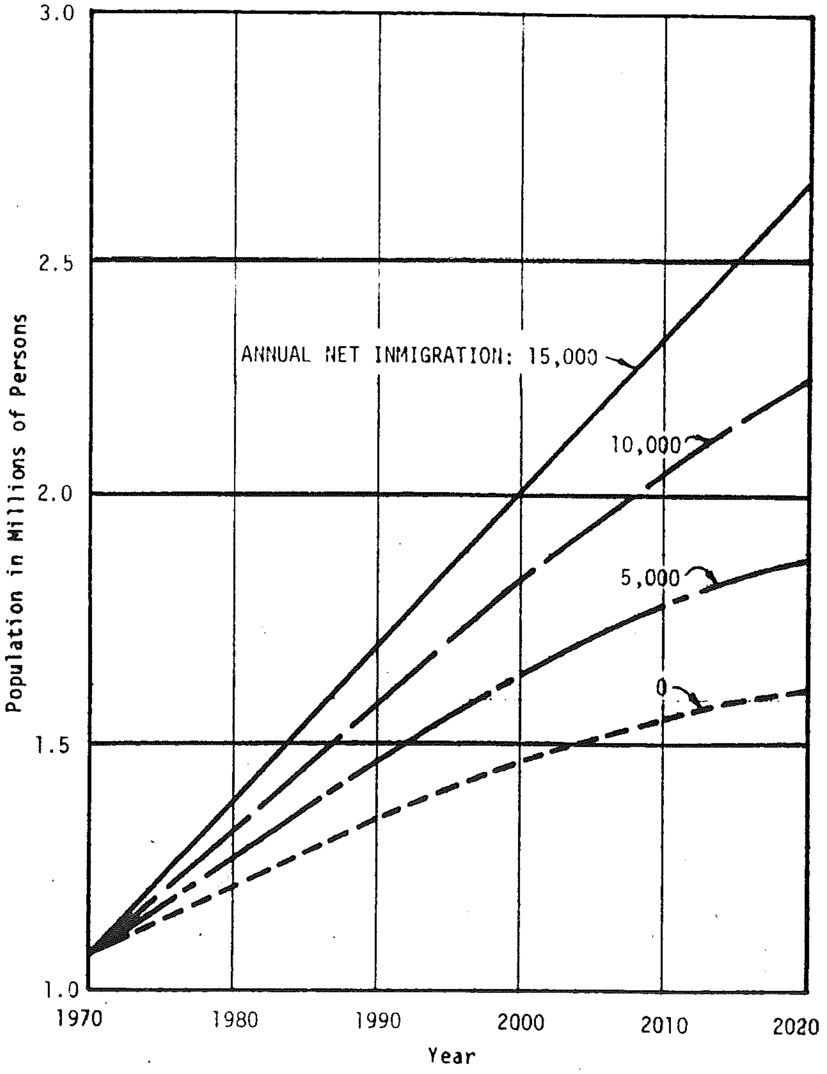
Urbanization is expected to continue, with buildout expected to occur in Santa Clara Subbasin before the year 2020.

Land use in the southern Santa Clara Valley was predominantly agricultural in 1974 (Figure III-4), with urban land uses (commercial, light industrial, residential) concentrated in Morgan Hill and Gilroy. A growing number of low density residential uses (ranchettes) occur primarily between and east of the two cities, while the foothills remain primarily open rangeland.

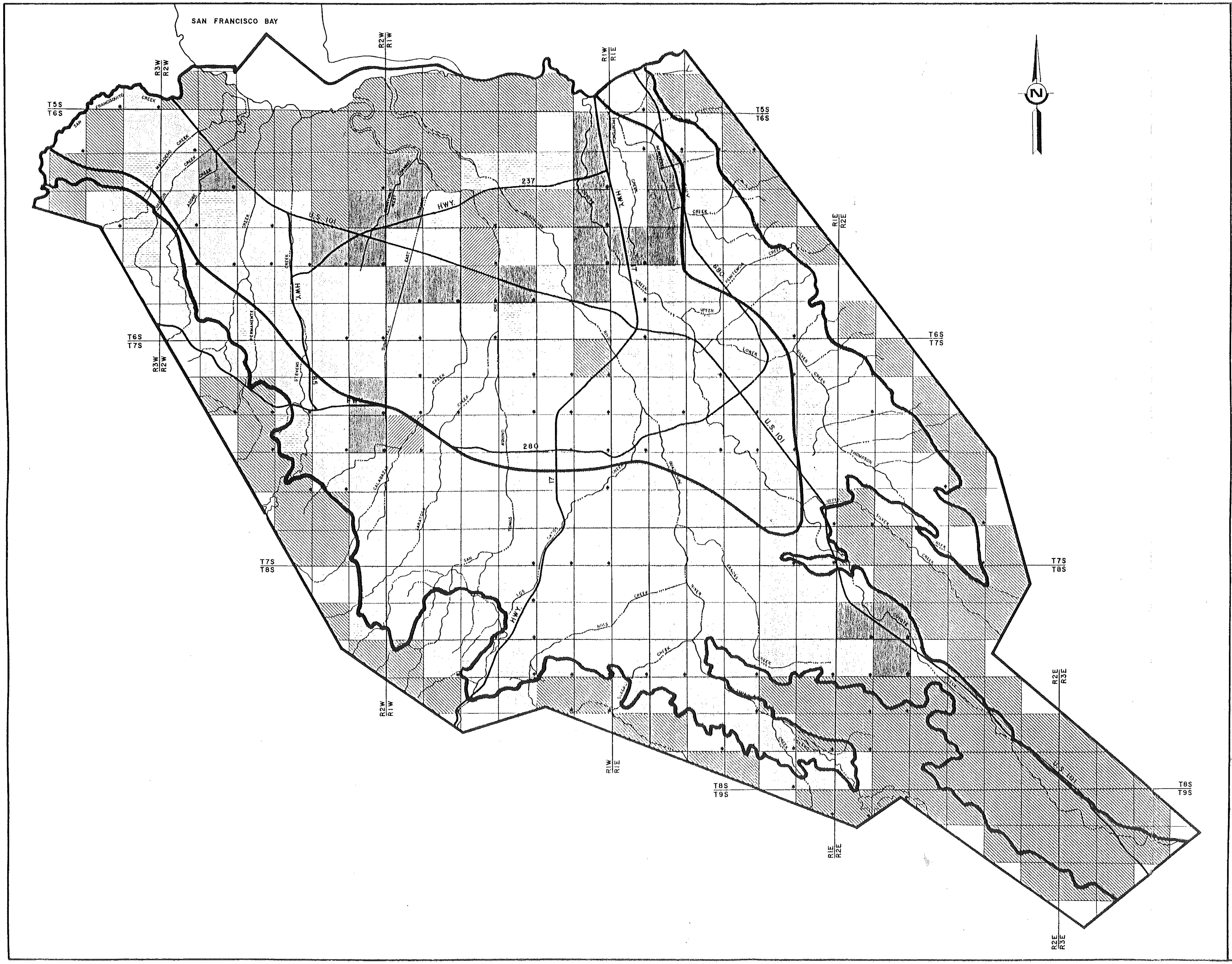
Land use changes in the southern valley over the past few decades have included a shift from orchards to truck and field crops. Orchards are expected to decline to insignificance within the next decade. In addition, irrigated lands are expected to continue to be converted to urban uses, particularly in the areas around and between Morgan Hill and Gilroy (Dunn, September 1982).

WATER DEMAND AND USE

As summarized in the Water Supply Plan reports, the Santa Clara Valley Water District has estimated future water demands for east and west portions of the Santa Clara Subbasin, and for the South County (Coyote and Llagas Subbasins). The methodology for projecting water demands is described in the March 1979 report, "Methodology for Projecting Water Needs in Santa Clara County."



Population Projections for Santa Clara County
(District, 1975) Figure III-2

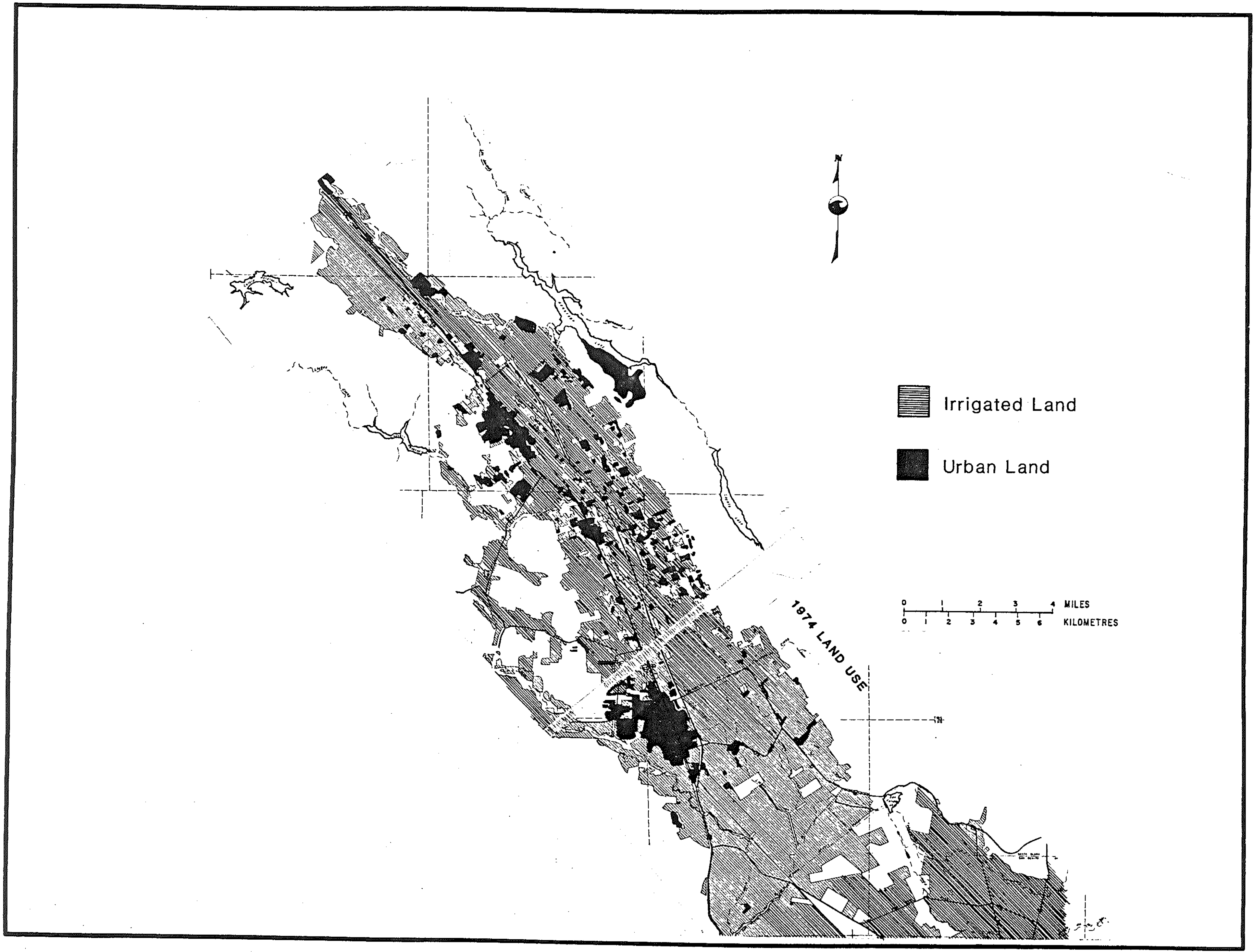


1984 Land Use
Santa Clara and
Coyote Subbasins

(SFRWQCB, 1985)

Figure III-3

Figure III-4



1974 Land Use, South Santa Clara County (DWR, 1984)

The projected water needs are based on projections of future land use in the County. In 1975, the District and County conducted a parcel-by-parcel inventory of vacant and agricultural land below the 600-foot contour. Future water demands were computed by determining the change in water use for each parcel as it converts to its ultimate use.

Water use factors were developed based on water usage patterns in 1975. Although per capita water usage has increased historically in the County, no future increase was projected, thus assuming significant future water conservation. Water use factors were determined for specific land uses including different densities of residential development, various types of commercial and industrial use, different crop types, and different landscaping uses.

The total annual water demand was computed as the sum of the water usage in the base year (1975) plus the incremental need resulting from the conversion of vacant and agricultural parcels to urban use.

Water demands are summarized in the following subsection for Santa Clara Subbasin (east and west portions) and South Santa Clara County (Coyote and Llagas Subbasins).

Santa Clara Subbasin. Water demand projections for the Santa Clara Subbasin are presented in the Water Supply Plan reports for the East and West Santa Clara Valleys. The projections are computed in terms of source of water supply: groundwater, Hetch-Hetchy, and District treated water.

Although the usage of water is not specified, it is predominantly for municipal and industrial purposes. Table III-1 is a summary of these projections.

Table III-1.

Water Demand Projections, acre-feet per year,
Santa Clara Subbasin.

	Water Source			
	Groundwater	Hetch-Hetchy	District Treated Water	Total
East Santa Clara Valley				
1990	102,600	15,700	72,000	190,300
2000	108,400	18,700	78,800	205,900
2020	114,400	21,500	91,200	227,100
West Santa Clara Valley				
1990	61,600	67,900	48,400	177,900
2000	60,400	71,400	53,000	184,900
2020	60,100	74,400	57,400	191,900
Total Santa Clara Subbasin				
1990	164,200	83,600	120,400	368,200
2000	168,800	90,100	131,800	390,800
2020	174,500	95,900	148,600	419,000

South County. Current municipal and industrial water demands and agricultural water demands were computed for each water service area within the Coyote and Llagas Subbasins. As in the Santa Clara Subbasin, future water demands were computed by determining the change in water use for individual parcels of land, and then summing the incremental change with the baseline water usage in 1975.

Considerable uncertainty exists in projecting water demand for the South County because little of the land has yet been converted to its ultimate urban use. Accordingly, upper and lower limits were defined for water demand projections (Figure III-5). These limits reflect differing assumptions regarding future residential densities and type of industry. Projections of agricultural water demand take into account the shift in south valley agriculture from orchards to annual crops, which generally require larger amounts of water. To project water demand, the midpoint of the range was selected. Projected water demands for the South County are listed in Table III-2.

Total Water Demand. The projected total water demands for the Santa Clara Subbasin, South County, and county as a whole are summarized in Table III-3. As indicated, water demands are projected to increase in the future, but at a decreasing rate. The projected water demands are a conservative estimate, largely because the following assumptions were used: (1) population growth will approximate the reasonable low growth rate, (2) per capita

Table III-2.
Projected Water Demands, South Santa Clara Valley.

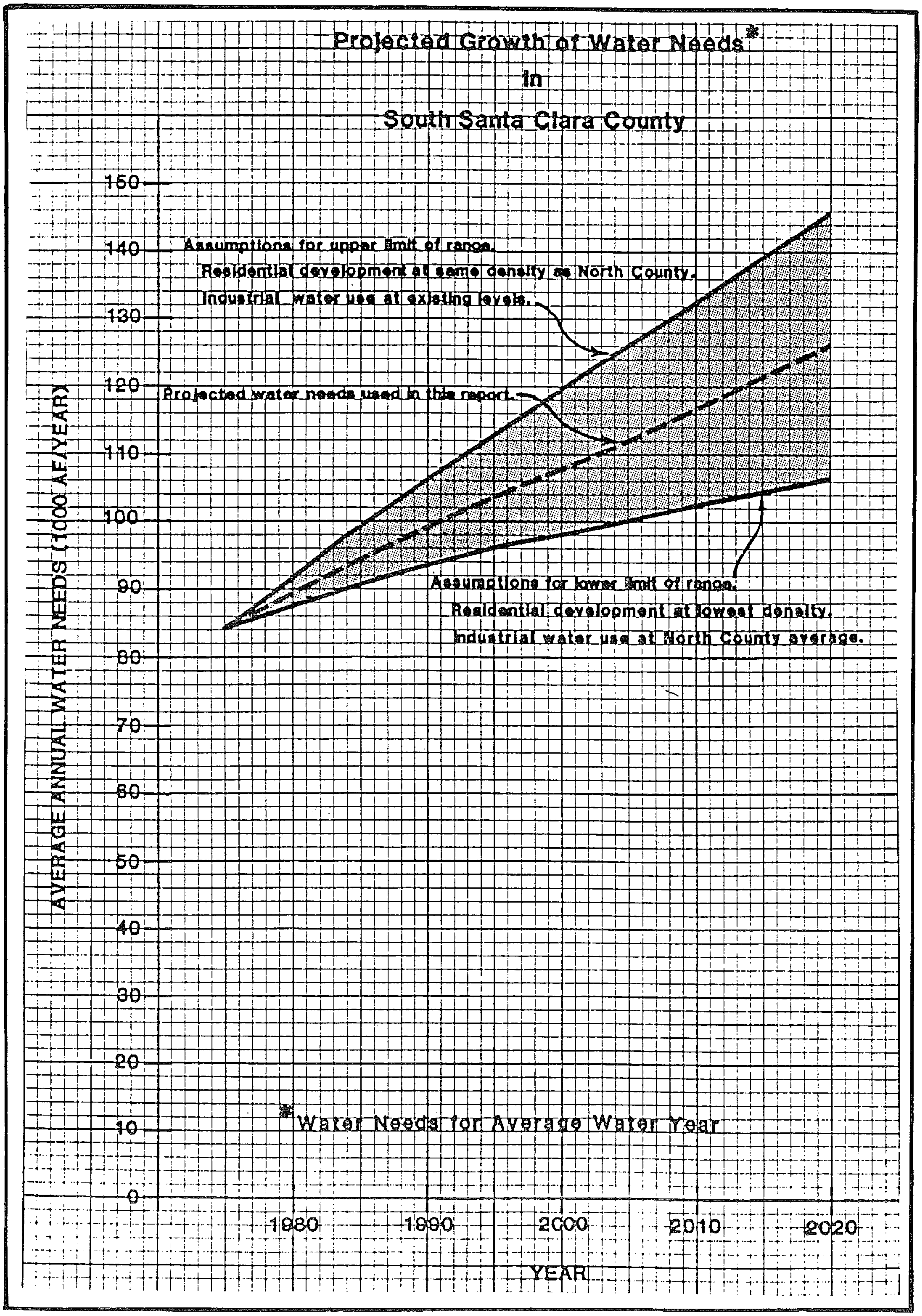
Year	Projected Water Demand, acre-feet		
	M & I	Agricultural	Total
Coyote Subbasin			
1990	3,500	9,700	13,200
2000	5,100	8,800	13,900
2010	6,700	7,900	14,600
2020	8,200	7,000	15,200
Llagas Subbasin			
1990	27,200	59,600	86,800
2000	38,700	55,100	93,800
2010	51,900	49,900	101,800
2020	65,200	45,500	110,700

Source: South Santa Clara County Water Supply Plan, 1983.

Table III-3.
Projected Water Demands, Santa Clara County.

Year	Projected Water Demand, acre-feet		
	North	South	Total
1990	368,200	100,000	468,200
2000	390,800	107,700	498,500
2020	419,000	125,900	544,900

Source: Water Supply Plan Reports.



Projected Growth of Water Needs,
South Santa Clara Valley
(District, 1975)

Figure III-5

water use will not increase, (3) outside residential water use will decline as a result of conservation efforts, and (4) groundwater pumpage in the South County will be metered and subject to a pump tax.

SECTION IV

WATER SUPPLY

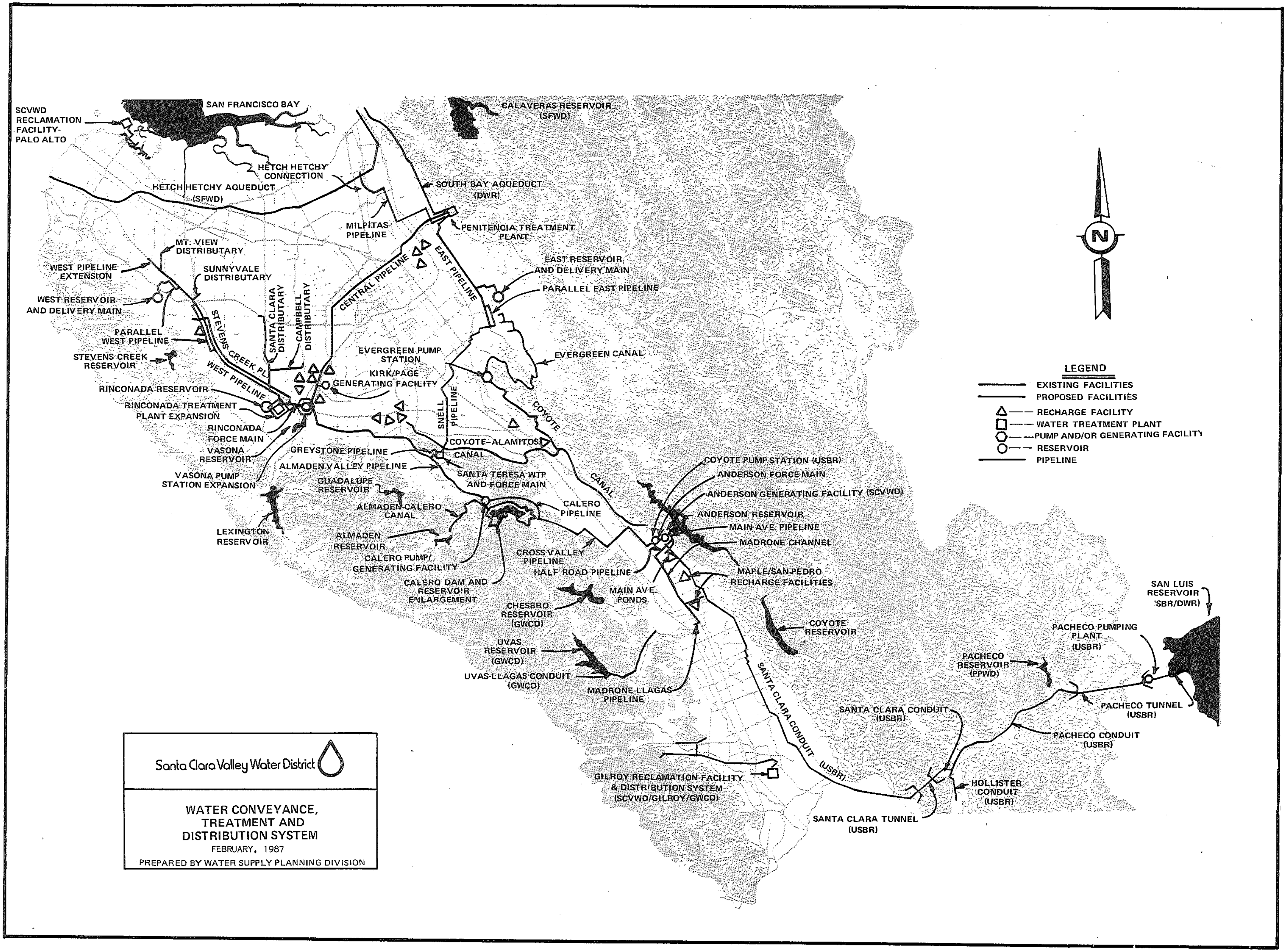
In response to increasing water demand, water supply agencies in the Santa Clara Valley have developed a variety of water sources, including imported surface water, local surface water, and groundwater. A portion of the surface water is treated and used directly, while the remainder is recharged to the groundwater basin. Water from the groundwater basin generally is not treated. A complex water distribution system operated by the District conveys untreated surface water to treatment plants or recharge facilities. Following treatment, drinking water is distributed to the valley's water purveyors through the District's water distribution system. Major features of the District's supply system are illustrated in Figure IV-1.

SOURCES

Sources of water supply for Santa Clara Valley include imported water, local surface water, and local groundwater. The general amount of water available from each source as of 1990 is illustrated in Figure IV-2. Reclaimed wastewater served as a minor source of supply for agricultural and landscape irrigation, but has been discontinued because of lack of demand except in the Gilroy area.

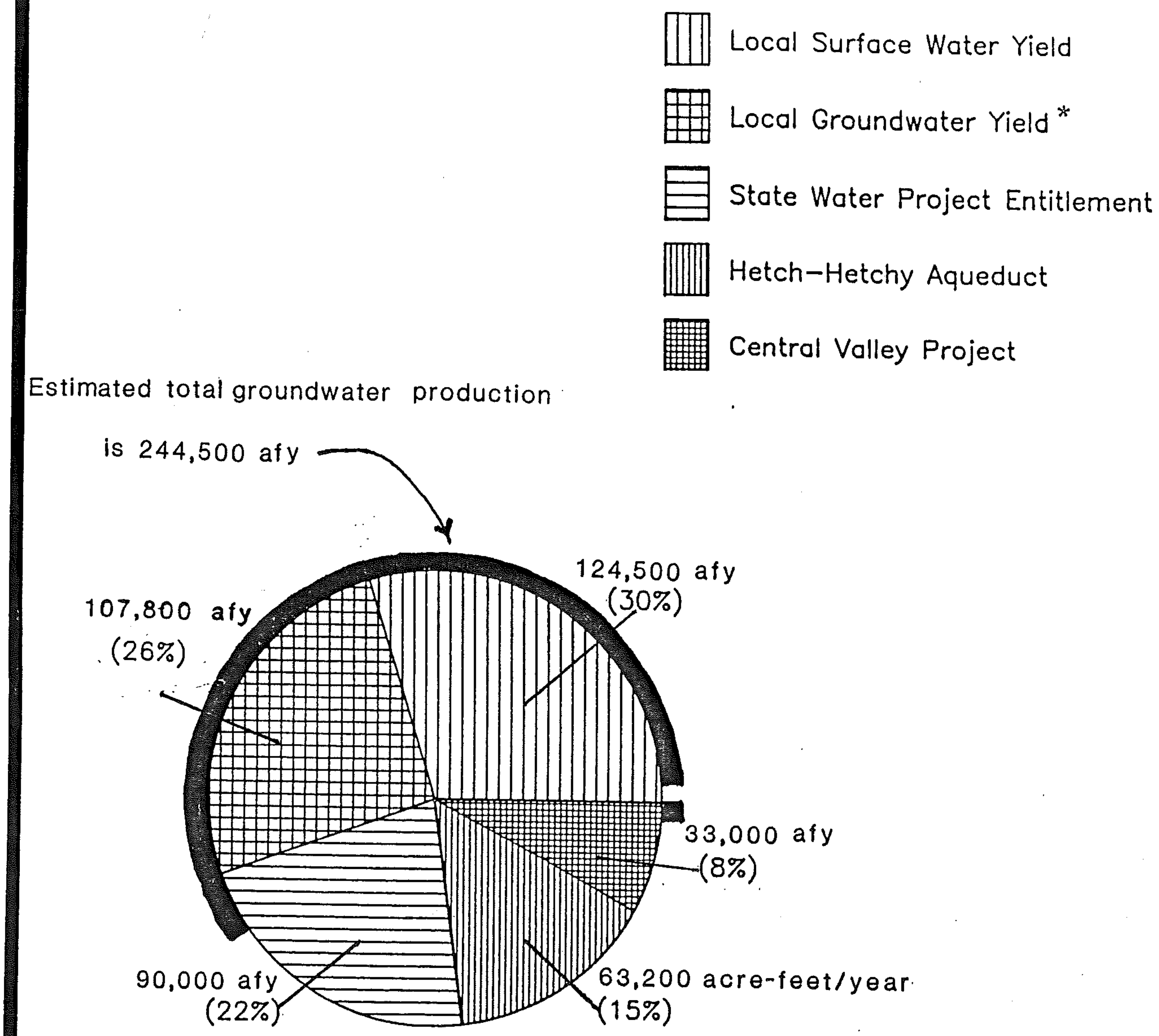
Imported Water. Imported surface water currently is available from two systems, the Hetch-Hetchy system operated by the City of San Francisco Water Department, and the South

Water Conveyance, Treatment and Distribution System



WATER CONVEYANCE, TREATMENT AND DISTRIBUTION SYSTEM
FEBRUARY, 1987
PREPARED BY WATER SUPPLY PLANNING DIVISION

Figure IV-1



* Does not include the local and imported surface water which is recharged artificially (more than 100,000 acre-feet/year) .

Sources of Water Supply to Santa Clara County, 1990

Figure IV-2

Bay Aqueduct, part of the California State Water Project. In the near future, water also will be imported to the valley through the San Felipe Division of the Central Valley Project, operated by the U.S. Bureau of Reclamation.

The Hetch-Hetchy Aqueduct, which conveys water from O'Shaughnessy Dam on the Tuolumne River to the Bay Area, crosses the northern portion of Santa Clara County. Potable water is available from this aqueduct to municipal water agencies, including the cities of Milpitas, San Jose, Santa Clara, Mountain View, Sunnyvale, and Palo Alto. Hetch-Hetchy also supplies the Purissima Hills Water District (Los Altos Hills), Stanford University, Moffett Field, and Agnews State Hospital.

Water deliveries to Santa Clara Valley from the Hetch-Hetchy system have increased significantly since signing of the first water contracts in 1952, reaching 66,980 acre-feet in 1985. This amount includes the guaranteed water delivery, approximately 58,000 acre-feet per year, and an additional residual water allotment. Projected Hetch-Hetchy supplies, which include only the guaranteed water delivery, are shown in Table IV-1.

Table IV-1.
Projected Hetch-Hetchy Aqueduct Deliveries.

Year	Delivery, acre-feet
1990	63,220
2000	68,970
2010	74,429
2020	74,429

The South Bay Aqueduct is the portion of the State Water Project (SWP) which conveys water from the Feather River and Sacramento-San Joaquin Delta to Alameda and Santa Clara counties. South Bay Aqueduct water, first delivered to Santa Clara County in June 1965, is available through the District to water retailers in the northern county. The terminus of the aqueduct is a steel tank near the District's Penitencia Water Treatment Plant on the east side of the valley; from there the raw water is conveyed either to groundwater recharge facilities or to the District's water treatment plants. SWP deliveries to Santa Clara County in 1985 amounted to nearly 102,000 acre-feet; of this amount, 81,000 acre-feet were treated and delivered directly to customers and the remainder was recharged to the groundwater basin.

The District is the contracting agency in Santa Clara County for SWP water. The contract signed in 1961 provides a water entitlement which increases in increments from 88,000 acre-feet in 1988 to 90,000 in 1989 and ultimately 100,000 acre-feet in 1994 and thereafter. Varying amounts of surplus SWP water also can be imported. Of the 102,000 acre-feet imported in 1985, 88,000 acre-feet represented the District's entitlement, nearly 10,000 acre-feet was surplus water, and 4,300 acre-feet was Central Valley Project water delivered through the SWP system by special agreement.

The District has considered the possibility of increasing the import of State Water Project beyond the current entitlement. As described in the Master Plan (SCVWD, 1975), the total capacity of the South Bay Aqueduct is 210,000 acre-feet per year, while scheduled entitlements for all contractors total 188,000. All or a portion of the remaining 22,000 acre-feet could be obtained by the District. Acquisition of this additional water, however, would involve not only the cost of the water but also planning, negotiation, and possible construction of additional pipelines or storage reservoirs. However, the State Water Project may not be able to fulfill all of its future contractual obligations, given its existing and approved facilities. The current firm yield of the project is 2.3 million acre-feet, which is about 55 percent of the total contracted amount of over 4.2 million acre-feet.

The San Felipe Division of the U.S. Bureau of Reclamation's Central Valley Project is designed to convey water from San Luis Reservoir to Santa Clara and San Benito counties and ultimately to Monterey and Santa Cruz counties. Water destined for Santa Clara County travels via the Pacheco Tunnel and Santa Clara Tunnel to the Santa Clara Conduit, which conveys the water to the foot of Anderson Dam. The San Felipe Division is scheduled for completion in June 1987.

The contract for delivery of San Felipe Project water was signed by the District and U.S. Bureau of Reclamation in 1977. The contract provides for minimum deliveries as shown in Table IV-2 (SCVWD, 1975). These deliveries consist of raw water destined for both the north and south valley

Table IV-2.

Central Valley Project Deliveries.

Year	Delivery, acre-feet		
	M & I	Agricultural	Total
1987	16,000	-0-	16,000
1996	52,000	15,000	67,000
2006	76,700	33,100	109,800
2016	99,700	33,100	132,800
2026	119,400	33,100	152,500

areas. Water for the south valley will be delivered through direct irrigation water deliveries or indirectly through groundwater recharge. The remainder will be recharged in the Coyote and Santa Clara Subbasins or treated at the District's Santa Teresa water treatment plant, now under construction.

Local Surface Water. Conservation of local surface water has been a primary purpose of the District since its inception. Currently, storage reservoirs have been constructed on nine of the streams draining into the valley. These reservoirs are the major source of supply for groundwater recharge; in addition, a small amount of local surface water is used directly.

The District owns and operates eight major reservoirs in the county with a total capacity of about 155,000 acre-feet. In addition, Gavilan Water Conservation District owns and operates two reservoirs in the south county, Uvas and

Chesbro. Lake Elsman, Williams, and McKenzie Reservoirs are operated by the San Jose Water Company. Pacheco Reservoir in southeast Santa Clara County is owned and operated by the Pacheco Pass Water District. Major characteristics of each reservoir are summarized in Table IV-3, while locations of all reservoirs are shown in Figure IV-1 with the exception of the San Jose Water Company reservoirs.

The drainage area yields for the major tributary areas in the County are shown in Table IV-4 (SCVWD, May 1981). The drainage area yield is defined as the portion of the surface water that can be put to beneficial use through surface diversions or recharge operations, given existing and future capacities of storage, recharge, and distribution facilities.

Conservation of local surface water could be increased somewhat either through construction of additional reservoirs, or through enlargement of existing structures. A number of alternative projects are summarized in the District's Master Plan (SCVWD, December 1975). The Almaden drainage has the greatest incremental untapped yield; accordingly, enlargement of Calero Dam and Reservoir is being considered at present. In addition, the Gavilan Water District has considered increasing its surface water supply; alternative projects are proposed in a report by Dunn (1982).

Table IV-3.
Major Reservoirs of Santa Clara County.

Agency/ Reservoir	Stream	Capacity, acre-feet
Santa Clara Valley Water District		
Almaden	Alamitos Ck	1,780
Calero	Arroyo Calero	10,050
Anderson	Coyote Ck	91,280
Coyote	Coyote Ck	23,670
Guadalupe	Guadalupe R	3,740
Lexington	Los Gatos Ck	20,210
Vasona	Los Gatos Ck	410
Stevens Ck	Stevens Ck	3,600
Gavilan Water District		
Chesbro	Llagas Ck	8,090
Uvas	Uvas Ck	10,000
San Jose Water Company		
Elsman	Los Gatos Ck	7,500
Williams	Los Gatos Ck	150
McKenzie	Los Gatos Ck	250
Pacheco Pass Water District		
Pacheco	Pacheco Ck	6,100

Sources: SCVWD, 1975; Dunn, 1982; SCVWD, April 1980.

Table IV-4.

Surface Water Yield of Major Tributary Areas (SCVWD, May 1981).

	Long-term Average, acre-feet/year
Santa Clara Valley Basin	89,513
Coyote Basin	10,884
Llagas Basin	24,068
Total	124,465

Groundwater. Three major groundwater subbasins provide water to Santa Clara County--the Santa Clara, Coyote, and Llagas. The physical characteristics of these subbasins are described in Section II, while management of the subbasins is described in Section V.

The natural yield of the groundwater basin has been computed as the amount of recharge that occurs annually as a result of percolation of streamflow from minor watersheds, rainfall, and irrigation, as well as subsurface inflow from surrounding highlands (SCVWD, May 1981). Estimates of the natural yield of the three subbasins are listed in Table IV-5.

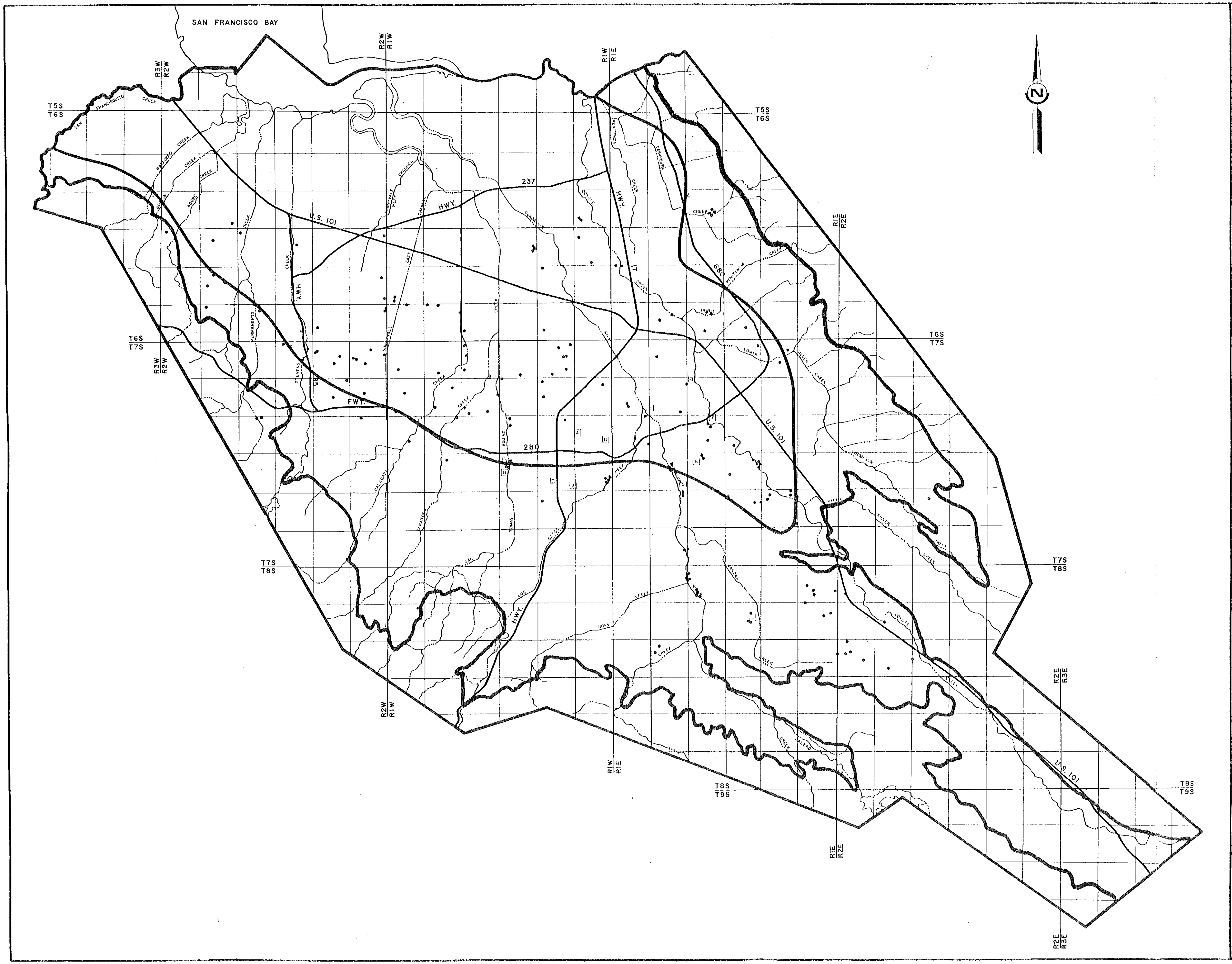
Table IV-5.
Estimated Natural Groundwater Yield
(District, May 1981).

Subbasin	Estimated Natural Yield, acre-feet/year
Santa Clara	58,200
Coyote	4,400
Llagas	45,200
Total	107,800

Groundwater in Santa Clara County is tapped through wells owned and operated by water retailers or private parties. In the Santa Clara and Coyote Subbasins, there are approximately 258 public supply wells, each defined as producing at least 16.5 acre-feet/year and serving 75 people or more (SFRWQCB, 1985). The locations of these wells are shown in Figure IV-3. In addition, these two subbasins are tapped by 1205 private wells (SFRWQCB, 1985). Figure IV-4 is a map showing the distribution of these wells, of which each produces less than 16.5 acre-feet/year.

The black arc partially surrounding the water supply graph in Figure IV-2 shows the estimated total groundwater production in 1990. This includes natural groundwater yield plus portions of water recharged underground from local surface water, SWP, and CVP. Thus, 58 percent of all water supplied in the basin will come from pumping of groundwater.

Groundwater pumpage in 1985 by retail water agencies in the Santa Clara Subbasin amounted to approximately 146,700 acre-feet; inclusion of private pumpage brings the total



LEGEND

● Well

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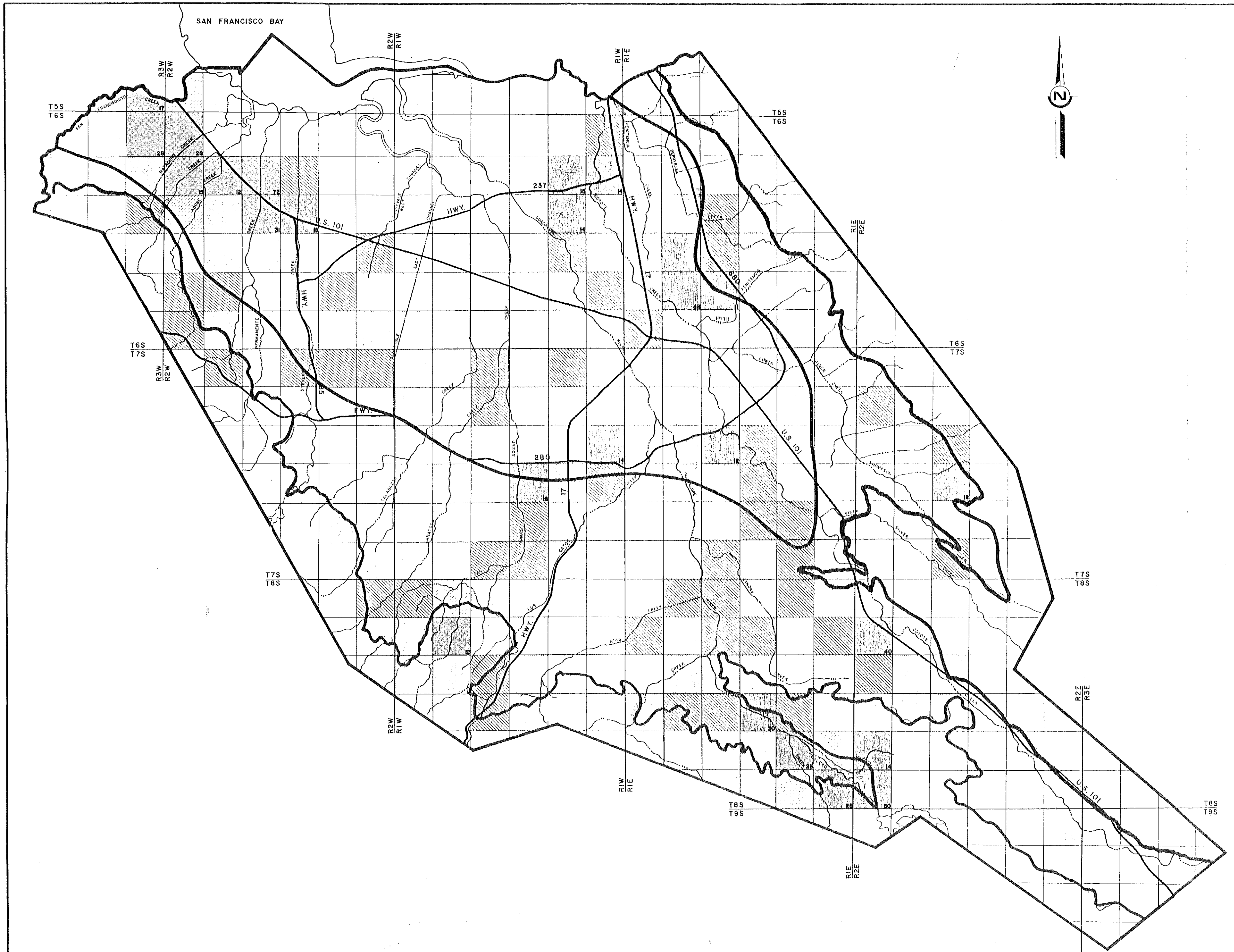
Municipal Wells,
Santa Clara and
Coyote Subbasins
(SFRWQCB, 1985)

Figure IV-3



LEGEND

□ 0 WELLS

□ 1-3 WELLS

▨ 4-6 WELLS

▒ 7-10 WELLS

■ >10 WELLS (ACTUAL NO. SHOWN)

Density of Private Wells, Santa Clara and Coyote Subbasins (SFRWQCB, 1985)

Figure IV-4

groundwater withdrawal to 181,300 acre-feet (SCVWD, July 1986). Total pumpage in the Coyote Subbasin is not known. The distribution of well production in the Santa Clara Subbasin and a portion of the Coyote Subbasin is illustrated in Figure IV-5.

Approximately 4000 wells, including inactive wells, exist in the Llagas Subbasin and Coyote Subbasins. These include private irrigation and domestic wells and a few municipal wells. The City of Morgan Hill owns and operates nine water supply wells; City of Gilroy has seven wells, some of which presently are inactive. The West San Martin Water Works, which serves the community of San Martin, has two wells. Essentially all of the water supply of the Llagas Subbasin is provided by groundwater. Because private pumpage for domestic and irrigation purposes predominates, withdrawal totals are not available for this subbasin. Municipal pumpage in 1983 by the cities of Morgan Hill and Gilroy amounted to 24,022 and 38,936 acre-feet, respectively (DOHS, 1984). No comparable pumpage value is available for San Martin.

WATER DISTRIBUTION SYSTEM

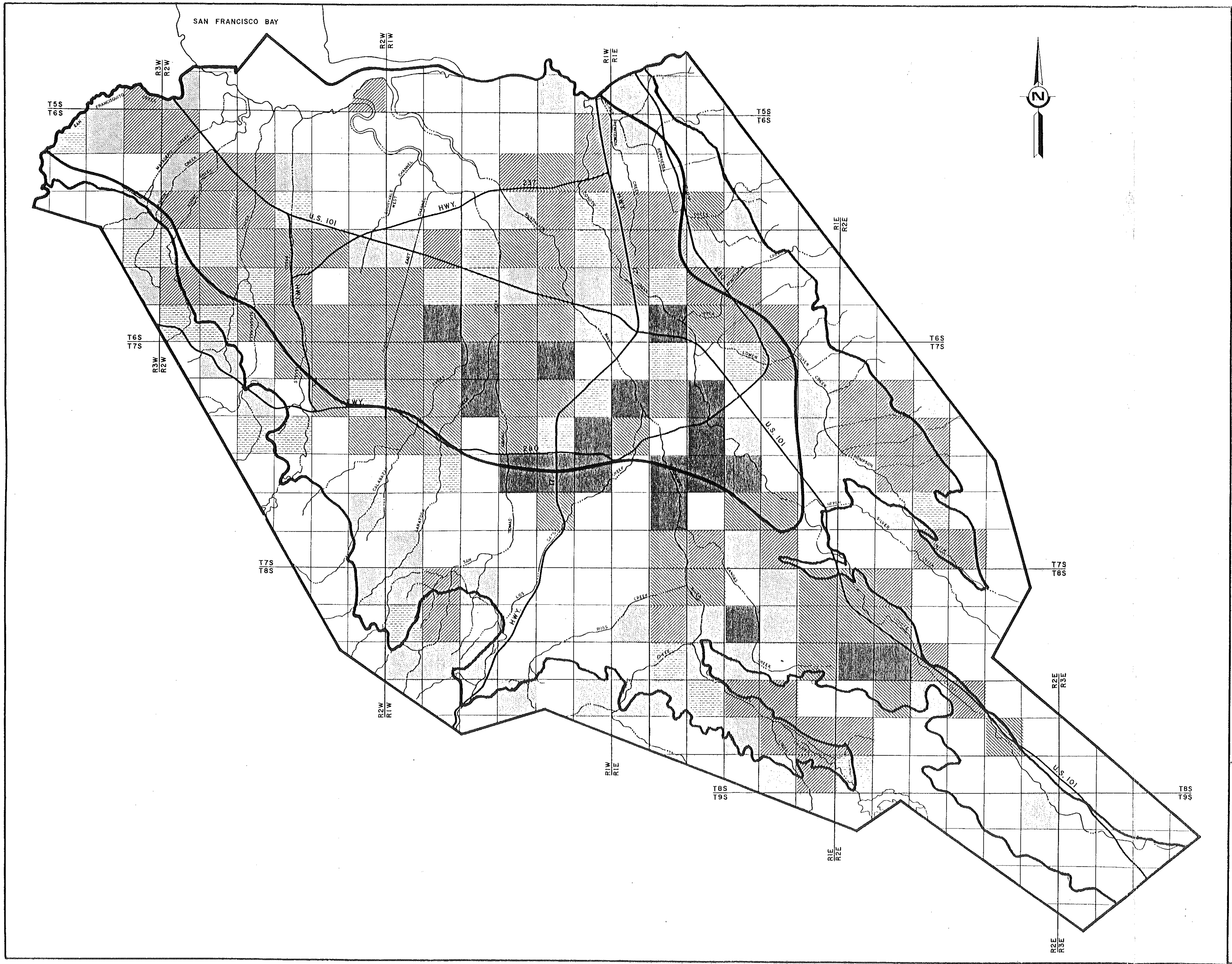
Water is imported into the Santa Clara Valley by means of three major aqueducts. Within the Santa Clara Valley, the District operates an extensive water distribution network, the Raw Water Conveyance System, which allows transport of untreated water from the aqueducts and local surface water reservoirs to storage at different locations, treatment at the water treatment plants, or to groundwater recharge facilities. In addition to this man-made system, water is also conveyed in natural streams--partially controlled by dams and diversion structures--and distributed by subsurface flow in the groundwater basin.

Aqueduct Systems. Three major aqueduct systems import, or will soon import, surface water to the Santa Clara Valley: Hetch-Hetchy, South Bay Aqueduct of the State Water Project, and San Felipe Division of the Central Valley Project.

The Hetch-Hetchy Aqueduct is a gravity flow pipeline that conveys Tuolumne River water to San Francisco and other Bay Area communities. Two pipelines cross at the Dumbarton Narrows and pass through northern Santa Clara County. Two dozen turnouts from the aqueduct distribute treated water to retailers along the pipeline route. The Hetch-Hetchy system is independent of other systems in the valley.

The South Bay Aqueduct extends for forty miles from the Sacramento-San Joaquin Delta to its terminus on the eastern side of Santa Clara Valley. The aqueduct, which consists of open lined canal and pipeline, conveys raw, untreated water. From the South Bay Aqueduct terminal tank, the water is diverted into the District's Raw Water Conveyance System to be conveyed either to the Penitencia or Rinconada treatment plants, to recharge ponds, or to Calero Reservoir.

The third aqueduct system, the San Felipe Division, is scheduled for completion in 1987. This system conveys water from San Luis Reservoir to a pumping station below Anderson



Well Production,
Santa Clara and
Coyote Subbasins

(SFRWQCB, 1985)

Figure IV-5

Reservoir in Santa Clara Valley via a system of pipelines and tunnels, the foremost of which is the Santa Clara Conduit, a 96-inch pipeline, which lies along the eastern side of southern Santa Clara Valley. Untreated water from the conduit can be distributed to recharge facilities in the south county, treated at the Santa Teresa water treatment facility, or diverted into the Raw Water Conveyance System in the north county for treatment at the Rinconada facility or for groundwater recharge.

Raw Water Conveyance System. Major existing and proposed facilities of the Raw Water Conveyance System are illustrated in Figure IV-1.

In southern Santa Clara Valley, the major sources of raw water are the Anderson-Coyote reservoir system on the east side of the valley, Chesbro and Uvas reservoirs on the west side, and in the near future, the Santa Clara Conduit. Conveyance facilities include the following:

> The Coyote Canal consists of lined and unlined canal which extends along the base of the eastern foothills. The canal conveys raw water from Anderson Reservoir to the Evergreen system, to the Coyote-Alamitos Canal, and to recharge ponds along Coyote Creek.
>
> The Evergreen system consists of a pumping station and canal and pipeline distribution system which delivers irrigation water to the Evergreen Valley area.
>
> The Almaden-Calero Canal is a concrete-lined canal which transfers water from Almaden Reservoir to Calero Reservoir.
>
> The Main Avenue Pipeline carries raw water from Anderson Reservoir southward to supply irrigated areas as well as to the Madrone Channel and Main Avenue recharge areas.

> The Anderson Force Main is a pipeline connecting Anderson Reservoir to the San Felipe project's Coyote pumping station as well as to the Cross Valley Pipeline.
>
> The newly completed Cross Valley Pipeline links the Santa Clara Conduit and Anderson-Coyote reservoir system on the east side of the southern Santa Clara valley with Calero Reservoir on the west side.

In northern Santa Clara Valley, the major sources of raw water are the South Bay Aqueduct, and various surface water reservoirs. Conveyance facilities include:

> The Central Pipeline conveys water westward from the South Bay Aqueduct to the Vasona Pumping Station on Los Gatos Creek. From there, the raw water can be conveyed to the Almaden Valley pipeline, Rinconada Force Main, or through turnouts to Los Gatos Creek and nearby recharge ponds.
>
> The Almaden Valley Pipeline links the Vasona Pumping Station and Calero Reservoir. The pipeline also has turnouts to nearby streams and recharge areas. Soon it will be tied to the Cross Valley Pipeline by the Calero Pipeline.
>
> The Rinconada Force Main is a pipeline conveying raw water from the Vasona station to the Rinconada Water Treatment Plant. The pipeline also has a turnout to the Stevens Creek Pipeline.
>
> The Stevens Creek Pipeline conveys raw water along the western foothills from the Rinconada Force Main to Stevens Creek. The pipeline has turnouts out to recharge areas along west side creeks.

To summarize, the Raw Water Conveyance System allows for flexible management of the local surface water and imported water sources. San Felipe water and local surface water from the Anderson-Coyote system is supplied to south county customers through direct distribution of irrigation water or indirectly through groundwater recharge. This water can also be transported to the north county for direct agricultural use, artificial recharge, or treatment at the Rinconada or future Santa Teresa water treatment facilities. South Bay Aqueduct water can be treated either at the Penitencia or Rinconada facilities, or can be released for artificial recharge at sites throughout the valley. Local surface water from west side streams is used to recharge the groundwater basin, while local water in the Almaden-Calero system is conveyed through the Raw Water Conveyance System for recharge or treatment. The Hetch-Hetchy Aqueduct is operated independently of the District system.

WATER TREATMENT

Treatment of surface water for municipal purposes includes coagulation, flocculation, filtration, and sedimentation to remove suspended materials, and disinfection to destroy disease-causing organisms. Common methods of disinfection are chlorination and chloramination.

Surface water destined for municipal use in the Santa Clara Valley is treated. Surface water imported via the Hetch-Hetchy Aqueduct is chlorinated at four facilities located along the route from the Tuolumne River to the valley; while local surface water provided by the San Jose Water Company is treated at its three small treatment plants.

The District operates two large water treatment plants--Penitencia and Rinconada--and has started construction of a third plant, Santa Teresa, which will process imported San Felipe water. The Penitencia Plant has a capacity of 40 million gallons per day (mgd), and treats water from the South Bay Aqueduct. In 1986, approximately 28,000 acre-feet were treated prior to delivery to the City of San Jose and San Jose Water Company. The Rinconada Plant, with a capacity of 75 mgd, treated nearly 45,000 acre-feet of imported South Bay Aqueduct water and over 7,000 acre-feet of local water from Calero Reservoir. Treated water is delivered to the California Water Service Company, San Jose Water Company, and cities of Cupertino, Santa Clara, and Sunnyvale.

Both the Rinconada and Penitencia water treatment plants operate at levels near their maximum sustained capacity for many days during each summer. The Rinconada plant, however, was sited and designed to allow for significant future expansion. Water from the San Felipe project will be treated primarily at the Santa Teresa plant, which will have a capacity of 100 mgd. Water from the San Felipe project also will be routed to the Rinconada plant by way of Calero Reservoir.

Groundwater typically is not treated, because passage through geologic sediments removes suspended sediments and organisms. Of the approximate 275 major supply wells in the valley, only 29 are chlorinated, while 12 are fluoridated.

The San Jose Water Company chlorinates nine of its 149 wells, the City of San Jose chlorinates three Evergreen wells, and the cities of Morgan Hill and Gilroy chlorinate water from their wells.

WATER SUPPLY AGENCIES

Water supply agencies in Santa Clara County include the Santa Clara Valley Water District, Gavilan Water District, and numerous water retailers.

Santa Clara Valley Water District. The Santa Clara Valley Water District is the principal water management agency and water wholesaler in Santa Clara County. With boundaries encompassing the entire county, the District has broad powers to plan, construct, manage, and operate facilities for water supply and flood control. Facilities owned and operated by the District include eight major reservoirs, two water treatment plants, numerous groundwater recharge facilities, and pipelines and pumping plants. In addition, the District maintains and monitors a network of groundwater monitor wells, surface water gages and sampling stations, and climatic stations. The District also serves as the major water wholesaler for the County and is the contracting agency for both the State Water Project and the Federal Central Valley Project.

The present District was created by the merger in 1968 of the Santa Clara Valley Water Conservation District (formed in 1929) and the Santa Clara County Flood Control and Water Conservation District, formed by the State

Legislature in 1951. As currently constituted, the District is governed by a Board of five elected directors and two at-large appointed directors. Sources of revenue for the District include property taxes, charges on groundwater withdrawal (pump tax), and charges for treated water.

Gavilan Water District. The Gavilan Water Conservation District was originally organized in 1938 as the South Santa Clara Valley Water Conservation District. The Gavilan District includes the southernmost portion of the Santa Clara Valley, extending from Middle and Tennant Avenues on the north to the county line (Pajaro River) on the south. The Gavilan District encompasses approximately two-thirds of the Llagas Subbasin.

The Gavilan District was formed to address the problem of groundwater overdraft and to augment water supplies. In response, the Gavilan District constructed two reservoirs, Chesbro and Uvas, which were completed in 1956 and 1957, respectively. These reservoirs are operated conjunctively with the groundwater basin; in other words, winter flows are stored in the reservoirs for gradual release to downstream recharge areas, where the water percolates to the groundwater. This water management program has resulted in the control of groundwater levels. Supplemental water for the Llagas Subbasin will be obtained through the Santa Clara Valley Water District's contract with the Federal government for San Felipe project water.

Water Purveyors. Major water purveyors, or retailers, in the county include nine municipal water agencies, six major private water companies, and a number of other entities. Locations of each are shown in Figure IV-6, while their major characteristics are summarized in Table IV-6. (DOHS, 1984).

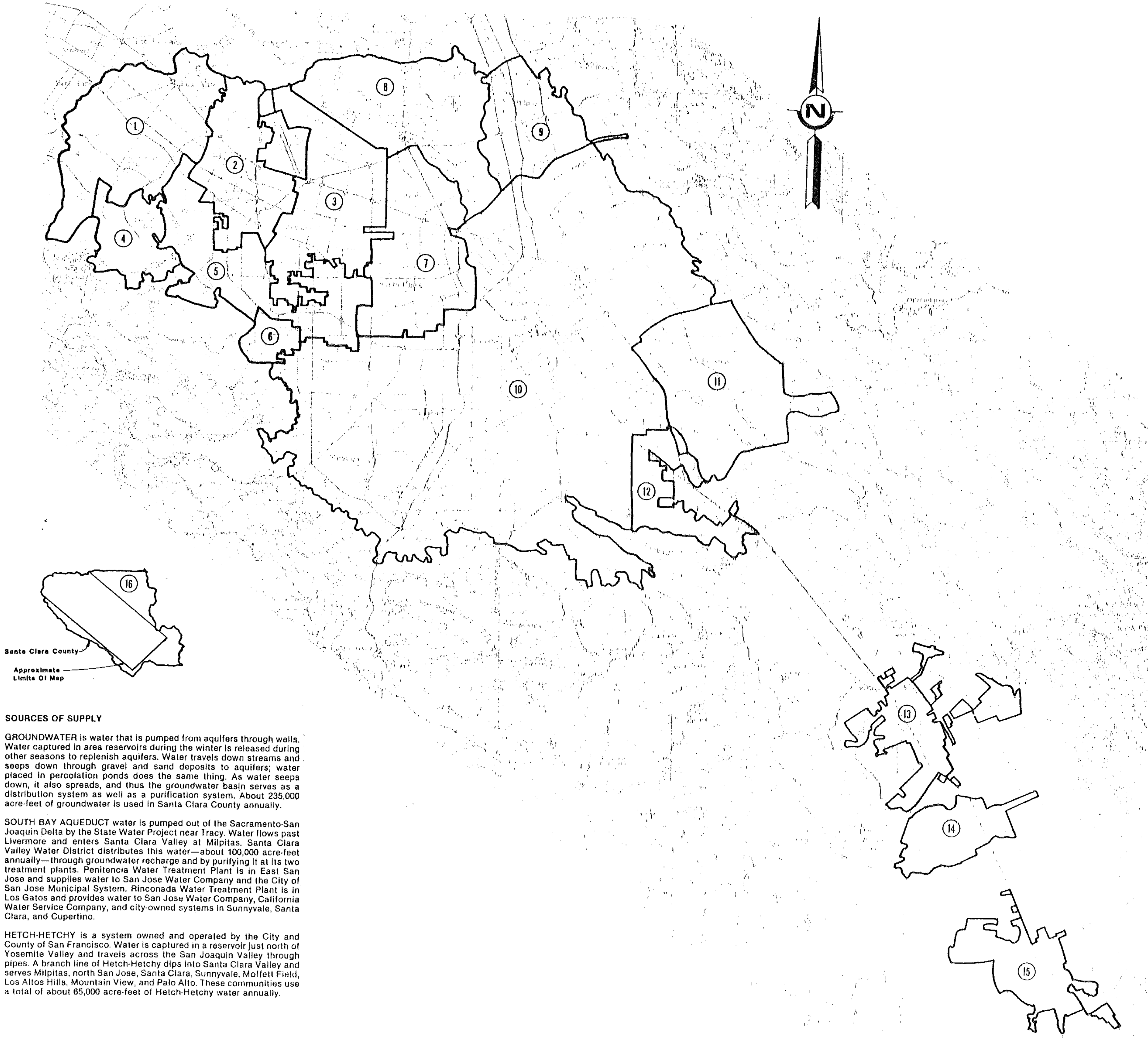
As indicated, purveyors provide water from a number of sources, including groundwater pumpage, local surface water, Hetch-Hetchy Aqueduct, and State Water Project, through the Santa Clara Valley Water District. Nine water suppliers rely on the Hetch-Hetchy system for their supply, including the City of Palo Alto, City of Milpitas, City of San Jose, Sunnyvale, City of Santa Clara, City of Mountain View, Purissima Hills Water District, Moffett Field, and Stanford University. Retailers using groundwater only are the Great Oaks Water Company and cities of Morgan Hill and Gilroy.

The largest retailer is the San Jose Water Company, which provides more than half of all the water sold. As shown in Figure IV-6, the company serves an extensive area which encompasses much of the City of San Jose, as well as the cities of Los Gatos and Saratoga. This large area is organized into ten zones, listed in Table IV-6. Sources of supply for the San Jose Water Company include groundwater pumped from 149 company wells, local surface water from the company's three reservoirs on Los Gatos Creek, and imported water from the State Water Project.

Table IV-6.
Characteristics of Major Water Purveyors (1)

Purveyor and Zone	1983 Production (acre-feet)	Population(2) Served	Wells in Use	Source of Water(3) (percent)			
				GW	HH	SCVWD	SW
Municipal Water Agencies							
Palo Alto	16,749	56,000	0(d)	1	99	0	0
Mountain View	15,950	60,000	3(b)	13	87	0	0
Sunnyvale(12)	28,755	212,000	10	25	43	32	0
Cupertino	2,819	25,000	2	0.2	0	99.8	0
Santa Clara	31,340	13,300	27	83	8	9	0
Milpitas	6,548	41,000	0(e)	0	100	0	0
City of San Jose							
Alviso	2,095	233(f)	0(g)	0	100	0	0
Evergreen(4,5)	7,074	43,600	3(h)	9	0	91	0
Edenvale	80(i)	5(f)	3	100	0	0	0
Morgan Hill	24,022	19,000	9	100	0	0	0
Gilroy	38,936	26,200	6(c)	100	0	0	0
Major Water Companies							
San Jose	142,995	701,000	149	55	0	33	12
Zones(6)							
Cambrian			49	95	0	5	0
Columbine(7)			19	20	0	80	0
Miguelito(8)			0	30	0	70	0
More			0	0	0	100	0
Cox			5	50	0	50	0
Vickery(9)			2	40	0	50	10
Montevina(10)			0	0	0	0	100
Dow(5)			57	85	0	10	5
Belgatos(11)			6	77	0	3	20
Great Oaks	14,396	61,330	10(a)	100	0	0	0
California Water (13)	13,641	17,000	38	42	0	58	0

-continued-



WATER IN SANTA CLARA VALLEY
SUPPLIERS AND SOURCES OF SUPPLY

PREPARED BY SANTA CLARA VALLEY WATER DISTRICT, 1984

1. City of Palo Alto (City-owned)
   Water supply: Hetch-Hetchy
2. City of Mountain View (City-owned)
   Water supply: Hetch-Hetchy, Groundwater
3. City of Sunnyvale (City-owned)
   Water supply: Groundwater, South Bay Aqueduct, Hetch-Hetchy
4. Purissima Hills Water District (Special District)
   Water supply: Hetch-Hetchy
5. California Water Service Company (Investor-owned)
   Water supply: Groundwater, South Bay Aqueduct, Hetch-Hetchy
6. City of Cupertino (City-owned)
   Water supply: South Bay Aqueduct, Groundwater
7. City of Santa Clara (City-owned)
   Water supply: Groundwater, South Bay Aqueduct, Hetch-Hetchy
8. City of San Jose (City-owned)
   Water supply: Hetch-Hetchy, Groundwater
9. City of Milpitas (City-owned)
   Water supply: Hetch-Hetchy
10. San Jose Water Company (Investor-owned)
    Water supply: Groundwater, South Bay Aqueduct, SJWC-operated treatment plant
11. City of San Jose (City-owned)
    Water supply: South Bay Aqueduct, Groundwater
12. Great Oaks Water Company (Privately owned)
    Water supply: Groundwater
13. City of Morgan Hill (City-owned)
    Water supply: Groundwater
14. West San Martin Water Works (Privately owned)
    Water supply: Groundwater
15. City of Gilroy (City-owned)
    Water supply: Groundwater
16. Santa Clara Valley Water District (Special District)
    Water supply: Groundwater, South Bay Aqueduct (The District serves the entire Santa Clara County with water supply and flood control programs. It is a wholesale water supplier to various city-owned and investor-owned utilities. It operates two treatment plants, eight dams, and also conducts programs in groundwater recharge, water reclamation, importation, distribution, and weather modification.)

SOURCES OF SUPPLY

GROUNDWATER is water that is pumped from aquifers through wells. Water captured in area reservoirs during the winter is released during other seasons to replenish aquifers. Water travels down streams and seeps down through gravel and sand deposits to aquifers; water placed in percolation ponds does the same thing. As water seeps down, it also spreads, and thus the groundwater basin serves as a distribution system as well as a purification system. About 235,000 acre-feet of groundwater is used in Santa Clara County annually.

SOUTH BAY AQUEDUCT water is pumped out of the Sacramento-San Joaquin Delta by the State Water Project near Tracy. Water flows past Livermore and enters Santa Clara Valley at Milpitas. Santa Clara Valley Water District distributes this water—about 100,000 acre-feet annually—through groundwater recharge and by purifying it at its two treatment plants. Penitencia Water Treatment Plant is in East San Jose and supplies water to San Jose Water Company and the City of San Jose Municipal System. Rinconada Water Treatment Plant is in Los Gatos and provides water to San Jose Water Company, California Water Service Company, and city-owned systems in Sunnyvale, Santa Clara, and Cupertino.

HETCH-HETCHY is a system owned and operated by the City and County of San Francisco. Water is captured in a reservoir just north of Yosemite Valley and travels across the San Joaquin Valley through pipes. A branch line of Hetch-Hetchy dips into Santa Clara Valley and serves Milpitas, north San Jose, Santa Clara, Sunnyvale, Moffett Field, Los Altos Hills, Mountain View, and Palo Alto. These communities use a total of about 65,000 acre-feet of Hetch-Hetchy water annually.

Water Purveyors and Sources of Supply

Figure IV-6

Table IV-6, continued.
Characteristics of Major Water Purveyors(1)

Purveyor and Zone	1983 Production (acre feet)	Population Served	Wells in Use	Source of Water(3) (percent) GW	HH	SCVWD	SW
Major Water Companies, continued							
West San Martin	no data	300	2	100	0	0	0
Redwood Mutual	15	1,300	1	60	0	0	40
Other Entities							
Purissima Hills Water District	1,467	6,500	0	0	100	0	0
Stanford Univ.	2,708	11,000	0	0	100	0	0
Moffett Field	1,502	no data	0	0	100	0	0

1. Systems with 200 or more hookups, except West San Martin Works.

2. Estimates from water purveyors when available. In other cases, population figures are from the purveyors' annual reports to DOHS.

3. GW is groundwater, HH is treated Hetch Hetchy water, SCVWD is treated South Bay Aqueduct water, and SW is local surface water.

4. GW percentage shown is average for Alviso and Evergreen Zones.

5. Some treated well water is used in this zone.

6. Breakouts to zones are approximate. Wells are assigned to zone serviced if located in another zone. Wells serving multiple zones are generally counted in both zones, but with production apportioned between zones.

7. Includes Upper Northwood, Pleasant Vista, San Ramon.

8. Includes Sunset Hills, Dutard, Alum Rock.

Table IV-6, continued

9. Includes Saratoga Hills, Elva, Crisp, Lumbertown, and the N.W. portion of Overlook.

10. Includes Greenridge, Mt. Springs, Ravina, Cypress, High Street, Mireval, and the S.E. portion of Overlook.

11. Includes Webb Canyon, Montego. Some treated well water is used.

12. There are three service zones in this system. Users north of Maude Avenue receive exclusively HH water. Other users receive a mix of HH and well water, or SCVWD water and a small proportion of well water.

13. A portion of this area near Santa Clara and north of Homestead Road receives groundwater exclusively.

a. Also three wells removed from service due to contamination.

b. Also two standby wells.

c. Also one well shut down due to high nitrate levels.

d. Also 10 standby wells.

e. Also two standby wells.

f. 5 hookups at commercial park; non-residential.

g. Groundwater from 4 wells were to be used beginning in January 1985.

h. Seasonal supplement to supply.

i. Estimate for 1984.

WATER COSTS

Hetch-Hetchy. Treated Hetch-Hetchy water is delivered by the City of San Francisco Water Department directly to retail customers. The cost to retailers in 1987 is $126/acre-foot.

State Water Project. The 1986 cost to the District of State Water Project entitlement water is $110/acre-foot; however, the cost through the year 2000 is expected to vary between $96 and $101/acre-foot. Surplus water and unscheduled deliveries cost approximately $23/acre-foot.

Central Valley Project. Costs to the District of Central Valley Project water, as soon as it is available, are $61/acre-foot for M & I water, $16.50 for agricultural water, and $24 for replacement (surplus) water. These costs will be adjusted every five years.

Water Charges. The District has the primary responsibility for management of the water resources of Santa Clara County. This responsibility has included management of the Santa Clara and Coyote Subbasins, development of surface water storage and conveyance facilities, and water treatment. The benefits of the District's management efforts are gained by local water users; accordingly, the District is authorized to collect water charges, including a groundwater pumpage charge, basic user charge, and treated water surcharge. The water charges are based on the District's pricing policy, which has two main concepts: (1) that water in a given benefit zone has a uniform value regardless of source or cost, and (2) that the user pays for the benefits received. Accordingly, water charges are levied in those zones of the county that benefit from management. These zones, shown in Figure IV-7, include Zone W-2 (Santa Clara Subbasin) and Zones W-3.1, W-3.2, W-3.3, and W-3.5 (Coyote Subbasin). Groundwater charges will be levied in Zones W-5 and W-6 starting July 1, 1987 (Llagas Subbasin). District water charges for the current fiscal year are summarized in Table IV-7.

As indicated, the current groundwater charge and equivalent basic user charge for the Santa Clara and Coyote Subbasins is $95/acre-foot for municipal and industrial usage and $23.75/acre-foot for agricultural use. Raw surface water delivered to Santa Clara Subbasin through the Evergreen system is priced at $69.75 for agricultural water and $141 for M & I water.

Gavilan Water Conservation District levies groundwater charges within their boundaries in Llagas Subbasin. In Gilroy pumpage is metered, while agricultural pumpage is approximated from crop factors. Charges are $7.00/acre-foot for agricultural water and $28.00/acre-foot for non-agricultural water. Raw surface water deliveries to Llagas Subbasin through the Half Road Lateral system are priced at $15.75/acre-foot.

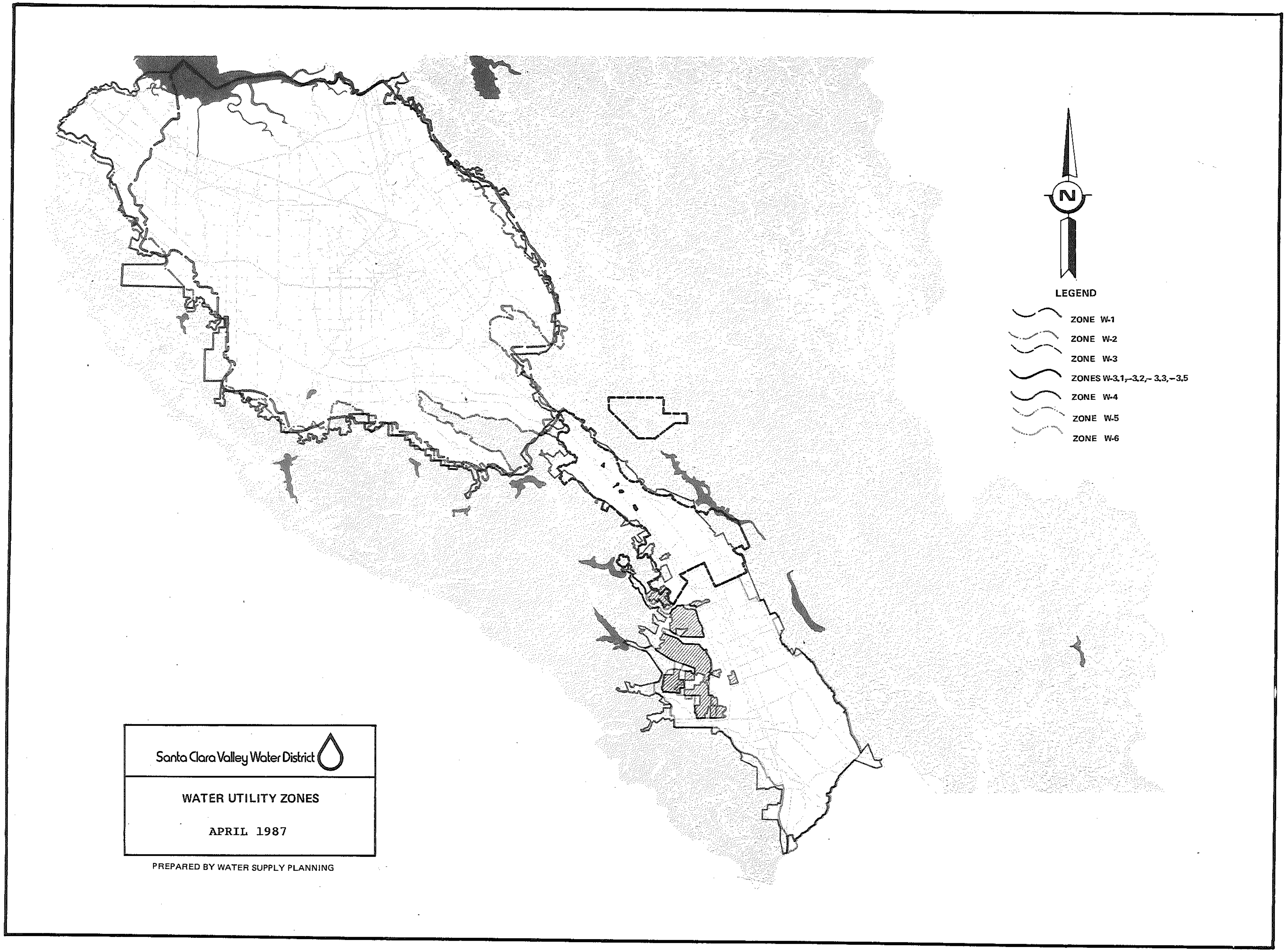

N
LEGEND
ZONE W-1
ZONE W-2
ZONE W-3
ZONES W-3.1,-3.2,- 3.3,-3.5
ZONE W-4
ZONE W-5
ZONE W-6
Santa Clara Valley Water District
WATER UTILITY ZONES
APRIL 1987
PREPARED BY WATER SUPPLY PLANNING

Figure IV-7

Water Utility Zones

The cost to retailers of treated imported surface water reflects the cost to the District of providing that water. Accordingly, the current charge to customers for treated State Water Project entitlement water is $180/acre-foot and $123/acre-foot for treated non-contract water (see Table IV-7).

Retail Costs. The cost of water to individual customers is determined by the various water retailers in the County. The cost to consumers reflects not only the cost of the water supply to the retailers, but also costs of pumping, storage, and transmission, treatment (if any), and administration. Current retail costs of water are not readily available from the numerous water retailers in the County. Nevertheless, information from the San Jose Water Company indicates costs to the municipal consumer of $300 to $400/acre-foot depending on amount of use. No analysis has been made of costs of untreated water for agricultural users.

WATER SUPPLY AND DEMAND

As indicated earlier, the water demand projections prepared by the District are conservative. However, these projections appear to be reasonable today. Projected water demand and average water supply for the years 2000 and 2020 are compared below for the Santa Clara Subbasin, and the Coyote and Llagas Subbasins in the South County, respectively.

Santa Clara Subbasin. As indicated in Table IV-8, a small shortfall in water supply could occur in the Santa Clara Subbasin in the year 2000. However, water supplies are sufficient for projected water demand in 2020. It should be noted that the comparison in Table IV-8 is a simplification of the water demand and supply situation, and does not account for annual or seasonal variations, demands for potable versus raw water, or for the specific demands of water retailers. The comparison assumes that yields from existing local watersheds will not be increased, with the exception of the additional water supply that may accrue from the planned enlargement of Calero Reservoir. Similarly, no surplus water or unscheduled deliveries are assumed to be available from the Hetch-Hetchy Aqueduct, State Water Project, or Central Valley Project. However, it is assumed that each project will supply the contracted amounts to the Santa Clara Subbasin. In the event of a shortfall in water supply, it could be compensated by diversion of water from the Coyote Subbasin, which generally has surplus supply, and by a temporary depletion of groundwater storage.

Table IV-8.

Water Demand and Supply, acre-feet, Santa Clara Subbasin.

	2000	2020	Comments
Water Supply			
Groundwater	58,200	58,200	1981 estimate. See Table IV-5.
Hetch-Hetchy	69,000	74,500	See Table IV-1
State Water Project	100,000	100,000	See section "Imported Water."
Central Valley Project*	66,800	99,100	See Tables IV-2 and IV-9.**
Local Surface Water	89,500	89,500	1981 estimate. See Table IV-4.
Total Supply	383,500	432,800	
Water Demand	390,754	419,045	See Table III-1.

* Contracted Amounts

** Assumes that Central Valley Project will supply 84,100 acre-feet/year in 2000 and 140,500 acre-feet/year in 2020. The available CVP supply is distributed between the Santa Clara and Llagas Subbasins such that any deficit in total supply is shared equally.

South County. Table IV-9 summarizes future water supply and demand for the Coyote Subbasin in the South County. As indicated, local water sources, including groundwater and surface water from the Anderson-Coyote reservoir system, are sufficient to meet water demands in the years 2000 and 2020. Surface water will be treated and distributed to users by way of groundwater recharge; existing recharge facilities along Coyote Creek currently have the capacity to percolate 12,800 acre-feet/year, and thus are sufficient for future needs.

Table IV-9.

Water Demand and Supply, acre-feet,
Coyote Subbasin.

	2000	2020	Comments
Local Water Supply			
Groundwater	4,400	4,400	See Table IV-5.
Local Surface Water	10,900	10,900	See Table IV-4.
Total Supply	15,300	15,300	
Water Demand	13,900	15,200	See Table III-2.

Water demand and supply for the Llagas Subbasin are summarized in Table IV-10. Local water sources, which include local groundwater and surface water, are not sufficient to meet future demands. However, imported water from the Central Valley Project will be available in 1987 to supplement local sources. This water either will be delivered directly for agricultural use or recharged to the groundwater through existing or planned recharge facilities. Nonetheless, a small shortfall could occur in the subbasin in the year 2000; as in the Santa Clara Subbasin, this shortfall could be compensated by diversion of water from the Coyote Subbasin and a temporary depletion of groundwater storage. Alternatively, San Felipe deliveries could be increased.

IMPACT OF DROUGHT

A brief analysis has been carried out to determine the availability of water supply during periods of drought or water supply deficiency. Two scenarios are envisioned: one assuming a moderate drought in which all sources of water supply are reduced to 75%, and another involving a severe drought in which water supply is reduced to 50%. The first drought is analogous to the 1928-1934 drought, when state-wide rainfall was 78% of normal, while the second drought is similar in severity to 1975-1977 conditions. In 1976 and 1977, annual rainfall was 65% and 45% of normal, respectively. The effects of both the moderate and severe droughts are examined assuming water supply and demand conditions in the years 2000 and 2020. It should be noted

Table IV-10.

Water Demand and Supply, acre-feet,
Llagas Subbasin.

	2000	2020	Comments
Local Water Supply			
Groundwater	45,200	45,200	See Table IV-5.
Surface Water	24,100	24,100	See Table IV-4.
Total Local Supply	69,300	69,300	
Imported Central Valley Project*	17,300	41,400	**
Total Supply	86,600	110,700	
Water Demand	93,800	110,700	See Table III-2.

* Contracted amounts

** Assumes that Central Valley Project will supply 84,100 acre-feet/year in 2000 and 140,500 acre-feet/year in 2020. The available CVP supply is distributed between the Santa Clara and Llagas Subbasins such that any deficit in total supply is shared equally.

The depletion of the Santa Clara Subbasin would approximate 24,800 and 10,600 acre-feet/year in 2000 and 2020, respectively. These are small amounts of water (less than 1%) relative to the total groundwater storage of 3,225,000 acre-feet. The storage capacity of the subbasin between depths of 110 and 210 feet is approximately 1,047,000 acre-feet (DWR, 1975), indicating that the subbasin yields about 10,470 acre-feet per foot of subbasin drawdown. Assuming that the groundwater level at the beginning of the drought is about 110 feet, then depletion of the subbasin of 24,800 or 10,600 acre-feet/year will result in average drawdowns across the subbasin of less than 3 feet/year and 1 foot/year, respectively, as long as drought conditions persist.

In the Coyote Subbasin, depletion of groundwater storage would not be necessary until 2020, at which time the annual overdraft would amount to only 700 acre-feet per year out of a total storage of 76,000 acre-feet, or about 1%. Assuming an initial water table depth of 25 feet, and a subbasin yield of about 275 acre-feet per foot of drawdown, then the drawdown needed to supply 700 acre-feet per year would be less than 3 feet/year.

Storage in the Llagas Subbasin would be tapped at rates of 9800 and 5600 acre-feet per year in 2000 and 2020, respectively. With a total groundwater storage of 475,000 acre-feet and subbasin yield of about 1700 acre-feet per foot, depletion of storage would result in a subbasin-wide drawdown of less than 6 feet/year in 2000 and about 3 feet/year in 2020.

Analysis of the effect of a moderate drought indicates that annual depletion of total groundwater storage would amount to less than 1 to 2 percent for the three subbasins. Accordingly, no absolute shortage of water would exist given a drought with any probable duration. However, it should be realized that drawdown of groundwater levels would not be uniform across the subbasins, but probably would be localized around existing well fields. In these areas, water level drawdowns would be considerably greater, and could result in problems including drying up of shallow wells, recurrence of land subsidence, and acceleration of seawater intrusion. Such problems could be mitigated through drilling of additional, deeper wells. Alternatively, water conservation efforts could be increased. It should be noted that a 20% reduction in demand compensates for most of the shortfall in supply during a moderate drought.

Table IV-12 summarizes water supply, water demand, and amounts of water needed from groundwater storage in the event of a severe drought. As indicated, significantly greater amounts of water would be extracted from groundwater storage to compensate for the temporary shortfall in normal supply.

Table IV-12.

Projected Water Supply and Demand During a Severe Drought, acre-feet/year.

	2000	2020
Water Supply *		
Santa Clara	191,800	216,400
Coyote	7,700	7,700
Llagas	43,300	55,400
Water Demand **		
Santa Clara	312,600	335,200
Coyote	11,100	12,200
Llagas	75,000	88,600
Water from Groundwater Storage		
Santa Clara	120,800	118,800
Coyote	3,400	4,500
Llagas	31,700	33,200

* Values are based on projected water supply from Tables IV-8,9, and 10, reduced to 50%.

** Values are based on projected water demand from Tables IV-8,9, and 10, reduced to 80% (20% conservation rate).

In the Santa Clara Subbasin, 120,800 and 118,800 acre-feet/year would be pumped under conditions in 2000 and 2020, respectively. These annual extraction amounts represent a depletion of the total storage of about 4%. Each would result in an average groundwater level decline of about 11 feet/year across the subbasin.

Water required from storage in the Coyote Subbasin would amount to 3,400 acre-feet in 2000 and 4,500 acre-feet in 2020. Such annual pumpage would deplete 4 to 6% of the total storage in this small subbasin, and result in water level declines of 12 feet/year under conditions in 2000, and 16 feet/year under 2020 conditions.

Similarly, a severe drought would result in pumpage of significant amounts of water from the Llagas Subbasin. The annual amounts listed in Table IV-12 represent withdrawals of 7% of total storage in 2000 and 2020. Such withdrawals would result in average groundwater declines of about 19 feet/year.

The impact of halving normal water supply could be far more severe than that of a moderate drought unless conservation efforts were more effective. As noted previously, water conservation in Santa Clara County amounted to 22% during the 1976-77 drought; however, rigorous water conservation and rationing in hard-hit Marin County resulted in a reduction of municipal water use to less than half previous levels. Such conservation could compensate for a severe drought.

Even assuming that conservation efforts reduced water demand by only 20%, ample water exists in groundwater storage to compensate for a severe drought persisting over a long period. Annual withdrawal from storage would range from about 4% to 7% of total storage, depending on the year and subbasin. As noted previously, however, pumpage probably would be concentrated, resulting in local problems such as water level decline, land subsidence, and seawater intrusion. In addition, the existing capacity of facilities to pump and transmit groundwater could be exceeded, and additional deep wells would have to be drilled.

SECTION V

CURRENT GROUNDWATER MANAGEMENT

CONCEPTS OF BASIN MANAGEMENT

The goal of groundwater basin management is to provide a sufficient quantity of water in areas of demand while maintaining the quality at the highest feasible level. Although groundwater is considered a renewable resource, a balance exists between the input (recharge) and the output (discharge) of a groundwater basin. A groundwater basin functions as a hydrologic unit, and therefore, withdrawals in one location affect the availability of groundwater in other locations.

Typically, groundwater development for water supply begins with a few scattered wells throughout a basin. As more pumping wells are established, the rate of extraction increases. In the absence of a coherent groundwater management plan, continued development could potentially deplete the groundwater resource (Todd, 1980).

This scenario of unplanned development underscores the importance of groundwater basin management. Maintenance of adequate supply requires not only an understanding of the total amount of water available in the basin (total storage), but also that which can be withdrawn on a yearly basis without producing negative side effects (perennial yield). Examples of these negative effects include depletion of the groundwater resource, development of uneconomic pumping conditions, degradation of groundwater quality, interference with prior water rights, and land subsidence caused by lowered water levels.

Conjunctive use, the coordinated and planned use of both surface water and groundwater resources such that water is conserved, is one method of groundwater basin management. The basic practice is to store surface water in reservoirs, and then recharge it to the groundwater basin at an optimal rate. Surface storage can then supply most annual requirements, while groundwater storage can serve as a supplement during dry years. In wet years surface water is utilized as much as possible and also is artificially recharged to augment the groundwater resources.

PURPOSES AND PARAMETERS

The perennial yield in the Santa Clara groundwater basin is governed by at least two undesirable consequences of overpumpage: land subsidence and saltwater intrusion. These two parameters are closely monitored and are mitigated through an extensive program of artificial recharge. In addition to these management concerns, shallow groundwater conditions have posed a flooding problem in years with high rainfall.

Land Subsidence. The Santa Clara Valley was the first region in the country to document land subsidence from groundwater withdrawals (Poland, 1971). Groundwater pumpage increased from 40,000 acre-feet per year in 1915 to 180,000 acre-feet per year in the 1960's. This pumpage resulted in a relatively continuous lowering of artesian head near San Jose from a level near ground surface to 150 - 200 feet below the land surface (Poland, 1971). This drawdown caused a maximum of almost 13 feet of irreversible land subsidence in San Jose by 1969 (Figure V-1). Land subsidence ceased in 1969-1970.

Land subsidence stems from the loss of artesian head in an aquifer. The result of this head loss is an increase in the effective overburden load. Sediments compact under this stress and land subsidence occurs. Compaction occurs in the most compressible layers, which in the Santa Clara Valley are the fine-grained, highly porous clay layers between the aquifers. Controlling subsidence involves raising the artesian head in the aquifers until it exceeds the residual excess pore pressure in the clay layers (aquitards). If this critical level can be exceeded and maintained, land subsidence can be stopped; however, it cannot be reversed.

Sea Water Intrusion. The inland migration of sea water is common in coastal groundwater basins. In California, intrusion has been documented in 14 major basins and is suspected to have occurred in 14 additional basins (DWR, Oct. 1975). Under natural conditions in which groundwater flows toward the sea, the salt water/groundwater interface is maintained near the coast or offshore. However, withdrawal of groundwater in significant quantities can alter this hydrodynamic boundary, drawing sea water inland.

In the Santa Clara Subbasin, saline groundwater was detected as early as 1910 in the shallow aquifer near Palo

Alto (Iwamura, 1980). Intrusion has occurred extensively near San Francisco Bay in the shallow aquifer (Figure V-1). The affected area extends approximately west to Palo Alto, east to Milpitas, and south along the Guadalupe River to the San Jose Municipal Airport. This condition has resulted from heavy groundwater pumpage and the inland migration of tidal saltwater along permeable stream channels. In addition, the deep aquifer has been affected, although to a much lesser extent than the shallow aquifer. Some contamination has been found to occur in isolated patterns which suggest contamination via abandoned wells.

Shallow Groundwater. Groundwater occurs at very shallow elevations in selected areas of all three subbasins. In the Baylands region of the Santa Clara Subbasin high water table conditions are present. In part, this situation results from poor drainage in the fine textured surficial materials. In addition, historical land subsidence has effectively raised the level of groundwater relative to land surface.

In the Laguna Seca region, situated in northwestern Coyote Subbasin along Santa Teresa Boulevard, a bedrock constriction forces groundwater to rise to shallow elevations. Portions of lands in Laguna Seca have been reclaimed for agriculture from a natural swamp by the installation of a subsurface drainage system. At this location flooding has occurred during periods of heavy rainfall accompanied by releases from Anderson Reservoir.

Until recently a monitor well with a continuous recorder was used to observe fluctuations in groundwater levels. If levels rose to within 5 feet of ground surface, water from Anderson Reservoir was diverted into Coyote Canal to prevent flooding (Iwamura, pers. comm, 1986). This well has since been destroyed and SCVWD presently uses judgment, based on past experience, on when to divert the surface water.

In Llagas Subbasin, south of Gilroy, groundwater exists under confined conditions and wells tapping deep aquifers were originally artesian. Extensive pumpage has subsequently reduced the head; however, when regional pumpage declines the piezometric surface rises to near land surface. The deep aquifer is monitored through the District's water level monitoring program. In addition, the shallow water table in this portion of Llagas Subbasin approaches ground surface on a seasonal basis because of poor drainage, agricultural return flows, and absence of pumpage in the shallow aquifer.

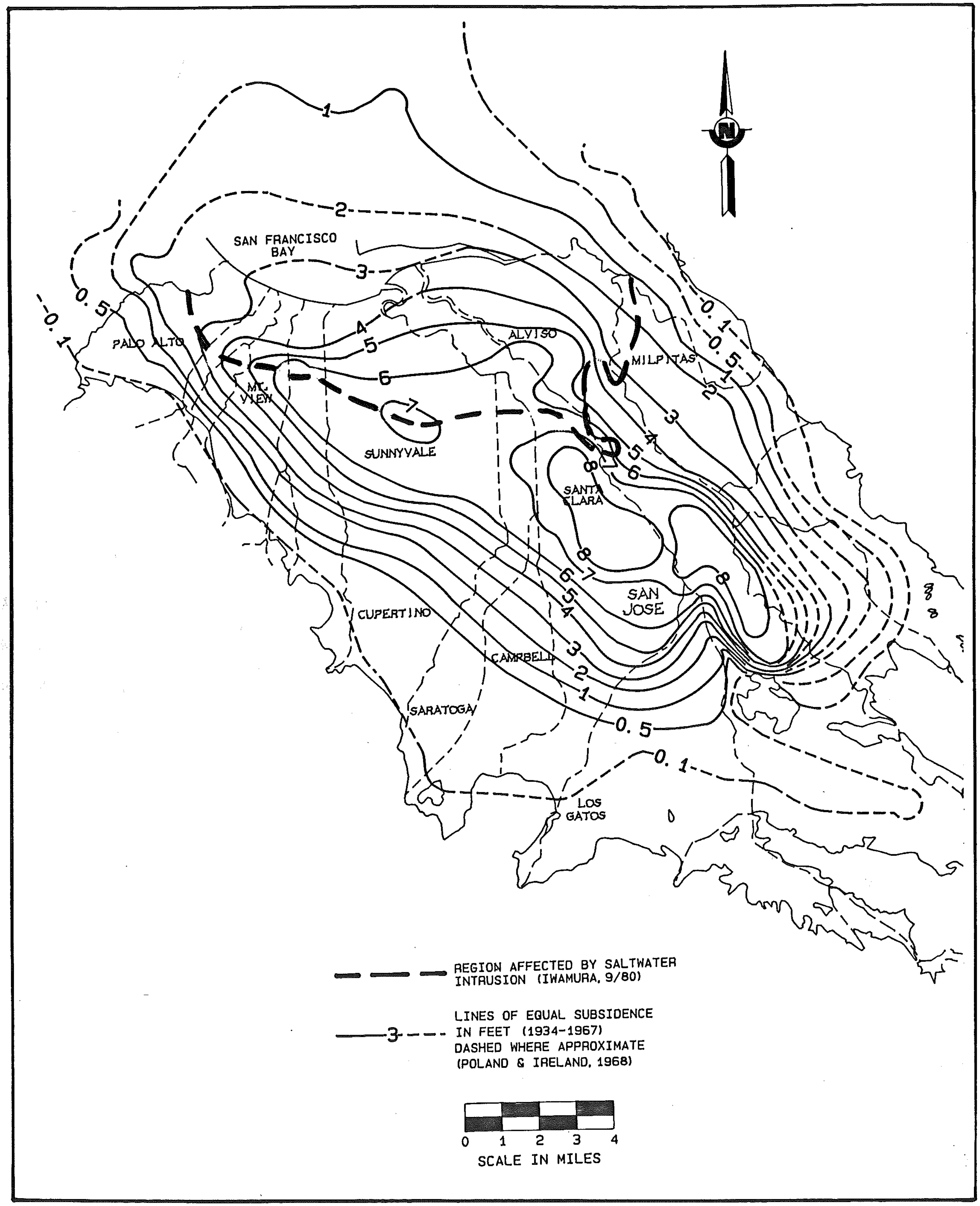
METHODS OF CONTROL

Artificial Recharge. In response to increased demands for groundwater and to problems associated with both saltwater intrusion and land subsidence, Santa Clara Valley Water District has conducted a program of artificial recharge to replenish the groundwater basin. It has been described as one of the most extensive programs in the country (Reichard and Bredehoeft, 1984). During the 1930's the first reservoirs and percolation facilities were established in Santa Clara County. When the South Bay

Aqueduct began delivering water into the basin in 1965, the amount of water available for artificial recharge was greatly increased. Currently, the program encompasses several rivers, creeks, and 14 groups of ponds with a total area exceeding 300 acres. The facilities have been grouped together into 7 categories based on location (Figure V-2). Data on each of these facilities are outlined in Table V-1.

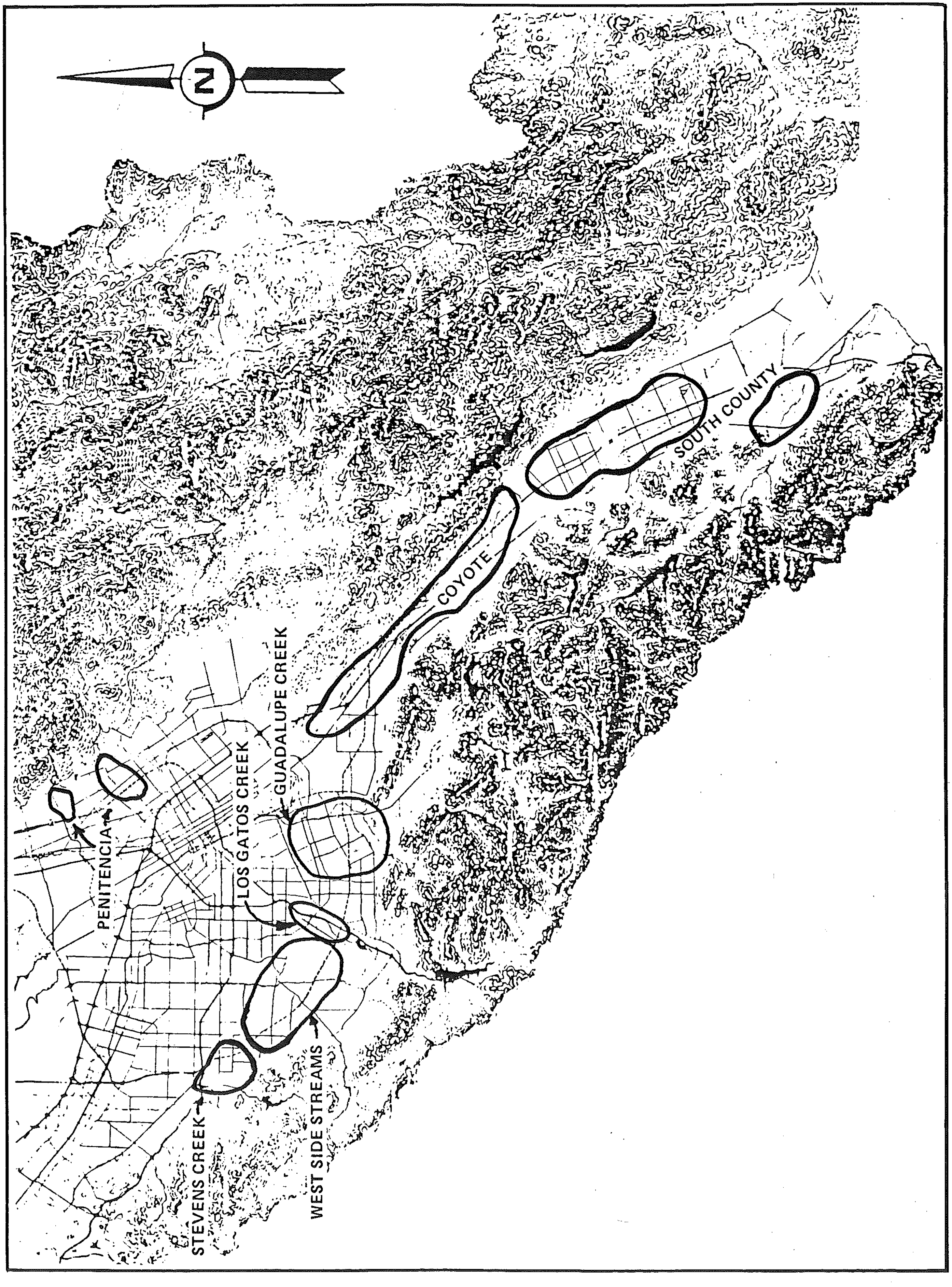
The rate of recharge for the various facilities ranges between 1 to 60 acre-feet per day, with the total volume of recharge estimated at 135,790 acre-feet in 1986 (SCVWD, 1986). In comparison natural groundwater yield for the entire groundwater basin is estimated to be 107,800 acre-feet (SCVWD, 1986). Existing recharge rates for each facility are calculated from field measurements and historical recharge data (SCVWD, 1977). The maximum rates listed on Table V-1 are determined based on the expansion of current operations and maintenance (SCVWD, 1977). Both existing and potential rates assume the availability of "unlimited 'clean' water supply", but do not account for losses due to evapotranspiration (SCVWD, 1977).

The DWR (1975) outlined the methodology of recharge facility operation. The amounts of water available from natural recharge and imported water are determined on an annual basis. An operational schedule is then developed based on available water and on constraints affecting ability to transmit and recharge water. These include maintenance and construction projects in stream channels,


SAN FRANCISCO BAY
PALO ALTO
MT. VIEW
ALVISO
MILPITAS
SUNNYVALE
SANTA CLARA
SAN JOSE
CUPERTINO
CAMPBELL
SARATOGA
LOS GATOS
N
0.1
0.5
1
2
3
4
5
6
7
8
REGION AFFECTED BY SALTWATER INTRUSION (IWAMURA, 9/80)
LINES OF EQUAL SUBSIDENCE IN FEET (1934-1967) DASHED WHERE APPROXIMATE (POLAND & IRELAND, 1968)
0
1
2
3
4
SCALE IN MILES

Land Subsidence and Saltwater Intrusion

Figure V-1



District Groundwater Recharge Systems

Figure V-2

Table V-1.
Characteristics of Recharge Facilities
(SCVWD, 1977)

NAME (DISTRICT SYSTEM)**	NUMBER OF PONDS and AREAS	TOTAL SURFACE AREA (acres)	MAX. RECHARGE RATE (acre ft/day)	SOURCE (L=local I= imported)
Alamitos (5)	2	15	15	L and I
Budd (4)	3	9	24	L and I
Camden (4)	3	62	20	L and I
Coyote (6)	1	30	56	L
Ford Road (6)	4	34	40	L
Guadalupe (5)	4	48	27	L and I
Kooser (5)	4	2	10	I
Los Capitancillos (5)	9	63	30	L and I
Main Avenue (6)	5	6	10	L
McClellan (2)	1	2.5	4	I
McClincey (4)	6	7	50	L and I
Oka (4)	4	17	10	L and I
Overfelt (1)	4	10	8	L and I
Page (4)	8	14	28	L and I
Penitencia (1)	6	14	17	L and I
Sunnyoaks (4)	4	3	8	L and I
TOTALS	68	326.5	357	

** District systems are depicted in Figure V-2. Numbers assigned to the seven systems are as follows:

(1) Penitencia
(2) Stevens Creek
(3) West Side Streams
(4) Los Gatos Creek
(5) Guadalupe Creek
(6) Coyote Creek
(7) South County

maintenance of recharge facilities, and recreational needs at the recharge facilities. Reservoir releases are then specified so as to meet water demands and to maximize total groundwater recharge. Those regions most in need of groundwater recharge because of deficiency are given first priority for recharge.

The potential for increasing the amount of artificial recharge as a means to meet anticipated increases in water demand through 2020 has been evaluated. In Coyote Subbasin, it has been determined that the perennial yield could be "increased significantly" by expanding the recharge program. However, this additional recharge is unnecessary because existing recharge facilites will be adequate to meet the projected demand until 2020 (SCVWD, 1983). New facilities are needed in Llagas Subbasin to supply an additional 20,000 acre feet/year (SCVWD, 1983). Of the ten potential sites that originally were investigated there, three pond sites were found to be suitable for artificial recharge. These ponds, to be operated as the Maple I and II and San Pedro recharge facilities, have a projected construction schedule beginning in 1988 (SCVWD, 1986). As of February 1986, this facility is the only planned expansion of the artificial recharge program.

In the Santa Clara Subbasin, the most effective means to enhance artificial recharge is through "more efficient use of existing facilities " (SCVWD, 1975). In 1986, an aggressive program was planned to obtain the maximum amount of recharge in existing facilities in Santa Clara and

Coyote Subbasins. Penitencia, Los Gatos, Steven's Creek, and Coyote recharge systems have been operated at full capacity in a program involving the timely construction of gravel dams, minimization of pond cleaning, and flocculation when turbidity becomes a problem.

Injection Barrier. In order to mitigate the seawater intrusion problem in the Palo Alto area, a seawater intrusion barrier was designed. Pairs of injection/extraction wells in the shallow aquifer were to be injected with reclaimed wastewater to create a hydraulic barrier to prevent further saltwater intrusion. The project was never fully operated due to technical problems and adverse economics associated with the high level treatment required. The barrier well field has been abandoned.

GROUNDWATER MONITORING

Groundwater Levels. Static water levels are measured quarterly by SCVWD staff at 250 sites throughout the county during a 10 day period. The candidate wells were selected on the basis of their location, depth, type of construction, and accessibility. The wells are distributed so as to provide a satisfactory method of determining the depth to groundwater of the major water bearing strata throughout Santa Clara County.

All wells have been characterized as to whether their measurements represent levels in the shallow water table aquifer or that of the deeper confined aquifers. Many of the wells are high capacity water supply wells that are perforated in more than one aquifer. For those wells without well logs, the District has qualified them by examining historical hydrographs which indicate the well response to stresses in the basin. The current program enables the District to distinguish water levels above and below the major aquitard. Piezometric surface maps for the confined zone represent a composite of levels from the multiple aquifers below the confined zone. Water table maps in the confined zone are not prepared as there are few wells that tap only the shallow zone, and the water table is not viewed as a continuum.

The monitoring program has been modified over the years as wells were destroyed and additional wells became available for measurement.

GROUNDWATER MODELS

DWR Groundwater Storage Models. DWR employed a finite difference model, originally developed in 1970, to simulate groundwater conditions in Santa Clara Subbasin (DWR, 1975) and Coyote/Llagas Subbasins (DWR, 1981). The Santa Clara Subbasin model consisted of 99 finite element cells, some of which were in a single layer while others contained three layers (shallow aquifer, aquitard, and deep aquifer). The boundary conditions were such that subsurface inflow to and outflow from the subbasin was assumed to be zero. The model was designed to test effects of changes in recharge and pumping patterns on groundwater and to verify the accuracy of the groundwater inventory. This model could not be calibrated because many nodes lacked historic water level records. Despite the limited utility of this model, it underscored the need for additional data.

The model developed for Coyote/Llagas subbasin had 69 cells and assumed a no-flow boundary except for the northernmost cell in Coyote Narrows, where groundwater flows out of the cell into the Santa Clara Subbasin. The delineation of the cells depended, in part, on the orientation of faults in the valley floor. Groundwater conditions throughout the basin were modeled as unconfined except in the southern portion of Llagas, where the extensive lacustrine clays effectively act as a confining layer. This model also could not be calibrated because of a lack of adequate historical data. It appeared that the understanding of the hydrology was not detailed enough to identify certain critical features affecting changes in groundwater levels.

Cost Benefit Model of Artificial Recharge. Reichard and Bredehoeft (1984) evaluated the cost and benefits of artificial recharge in the Santa Clara Subbasin. The goal of the model was to estimate the average long term effects of artificial recharge on water levels.

A number of simplifying assumptions were made in this modeling effort. The basin was modeled as a two layered system with the confined zone characterized as a single continuous aquifer separated by a series of 10 foot thick clay layers. In addition, the seawater intrusion effects were assumed negligible. In general, computer generated water levels matched well with actual water levels; however local features were "poorly reproduced" due to the simplification of the hydrogeology.

The effectiveness of the artificial recharge program in maintaining water levels over a 40-year period (1966 - 2060) was evaluated. Computer simulation with and without artificial recharge revealed that "the artificial recharge program in Santa Clara Valley has maintained hydraulic heads at a significantly higher level than they would have been otherwise." Results indicate that groundwater levels would not be reduced "drastically" in the absence of artifical recharge. However, the recharge program does provide a buffer in the event of increased pumpage or drought. Simulation of drought indicated that groundwater levels would be drawn down 200 feet and 350 feet below sea level with and without artificial recharge, respectively.

For the 40-year period land subsidence would have averaged 1 foot in the center of the valley without artificial recharge. With artificial recharge, there was no subsidence in the valley.

A summary of the discounted costs and benefits of artificial recharge are summarized in Table V-2. This analysis indicated that "the discounted benefits of continuing the artificial recharge program are from 1.5 to almost 2 times the discounted costs." However, it noted

Table V-2.

Cost-Benefit Analysis of Artificial Recharge

(from Reichard and Bredehoeft, 1984).

Discounted Costs of Artificial Recharge (million 1982 dollars)		
Land ($32,000/acre x 324 acres)	10.4	10.4
Operation ($480,000/year)	6.4	4.6
TOTAL	17.0	15.0
Discounted Benefits of Subsidence and Pumping Lift Reduction (million 1982 dollars)		
Subsidence Reduction	8.2	8.0
Reduced Average Pumping Lift ($1,679,000/year)	22.4	16.4
TOTAL	31.0	24.0

further that "the capital costs of starting a new recharge program would outweigh the benefits" in light of the present value of land (Reichard and Bredehoeft, 1984).

DWR Increased Groundwater Storage Model for Santa Clara Subbasin. The DWR developed a computer model to assist in an investigation of the feasibility of increasing the groundwater storage in the Santa Clara Subbasin (DWR, 1985). This additional water, available when the State Water Project could export excess water, would be recharged and subsequently withdrawn when the State Water Project was unable to meet entitlement delivery. The basic nodal configuration employed in the 1975 Santa Clara Subbasin model, described previously, was altered. The confined zone was extended further south with the resulting 149 nodes then reduced to four nodes, categorized as follows: 1) totally unconfined layer, 2) unconfined layer, 3) confined layer, and 4) fixed head. This step was warranted by the scope of the investigation, which was at the reconnaissance level. Another feature of the model was the utilization of kriging to interpolate water levels as opposed to the standard method of contouring water levels. This technique was applied for several reasons including: semi-annual water level information was required while contour maps are prepared on an annual basis, and there is a built-in subjectivity factor in hand contouring that varies from map to map.

This model was calibrated with kriged water levels in agreement with historical water levels. The additional recharge capacity available was determined to be 11,070 acre feet/6-months in the summer and 10,530 acre-feet/6-months in the winter.

SCVWD U.S.G.S. Groundwater Model. In 1985, the District evaluated several models and selected the MacDonald/Harbaugh U.S.G.S. three-dimensional model for application to Santa Clara Valley groundwater basin. The reasons for choosing the model were: 1) the U.S.G.S. model had good documentation, 2) the model was being used throughout the industry, 3) the U.S.G.S. continued to update the model, 4) the finite difference mathematics is simpler, and 5) the rectangular grid would fit the District's existing data.

The model is structured so that input to the program is divided into seven packages, each of which have their own individually developed input streams. The model was being developed in stages defined by each individual package. Each stage involved development of the data, program development, program changes, and draft documentation. Development of data first involved accumulation and review of available data. It was at this stage that any missing data were derived or estimated, if necessary. The program development stage involved manipulation of the data so that it coincided with the input structure of the model. Some of the data available did not meet the input requirements of the model and in these cases programing changes had to be made to the model. The final phase of each stage is the draft documentation. This is the documentation of the data being used, the programs developed to prepare the data, and the changes made to the model. The documentation was being developed so that three reports could be developed at the end of the project: the programers manual, the operators manual, and an overall report on the model.

At the end of the development of all the packages, the model would then be calibrated for the years 1970 to 1977. Following calibration, the documentation and final report will be completed. The model is expected to be a first cut working model which will give general results depending upon the accuracy of the calibration. The model will require a continued effort to obtain gradually increased levels of accuracy.

SECTION VI

WATER QUALITY

The quality of surface water and groundwater in the Santa Clara Basin is influenced by naturally occurring and human-introduced constituents. Precipitation contains only minor amounts of dissolved chemicals; however, upon reaching the earth's surface, it dissolves minerals in soil and rock during overland flow and subsurface percolation. The quantity of dissolved constituents are increased, while the chemical makeup depends on the chemistry of local soils and geology. Artificially induced changes through agricultural, residential, and industrial activities have also modified water quality. Before surface water is used for potable purposes, it is treated to meet aesthetic and health-related drinking water requirements. Groundwater, on the other hand, usually meets the necessary water quality standards without well head treatment, although some groundwater is chlorinated for disinfection purposes.

SURFACE WATER QUALITY

Local Surface Water. Surface water in the Santa Clara Valley is generally a calcium-magnesium bicarbonate type, and typically is hard to very hard. In terms of total dissolved solids (TDS), streams draining the Santa Cruz Mountains have a lower mineral content than streams draining the Diablo Range (USGS, 1971). Typical TDS values measured in Coyote Creek below Anderson Reservoir range from

170 to 250 milligrams per liter (mg/l). The range of TDS values is slightly lower (150 to 250 mg/l) for Llagas Creek below Chesbro Reservoir and for Uvas Creek below Uvas Reservoir (SCVWD, 1983). An increase in median TDS measured in Guadalupe River and Coyote Creek downstream from urban areas may be related to dry season urban runoff (USGS, 1986).

In 1979 the District and the U.S. Geological Survey began a cooperative stream monitoring program to assist in the evaluation of long term variations in water quality. This program encompasses 12 stations on Los Gatos, Coyote, and Llagas Creeks and Guadalupe River. The individual stations were selected based on the existence of a streamflow measuring station and historical water quality data and the location near a reservoir release point, recharge facility, urban area, or San Francisco Bay. Water samples are analyzed eight times a year for specific conductance, pH, temperature, dissolved oxygen, hardness, alkalinity, and major cations and anions. Dissolved metals, total organic carbon, biocides, and total and fecal coliform are measured biannually (SCVWD, 1984). The data from 1979 through 1981 are available in report form (USGS, 1986); more recent data are still in raw form.

The conclusions based on early data (1979-1981) were tentative, but indicate elevated mineral concentrations attributable to geological, agricultural, and urban sources (USGS, 1986). Fifteen biocides were detected in surface waters generally at or near detectable levels. Malathion concentrations in excess of USEPA criterion for freshwater aquatic life were reported in nearly all stations subsequent to the use of the insecticide in 1981 for control of the Mediterranean Fruit Fly. Based on the initial sampling effort, fecal-coliform and total coliform bacteria were the most troublesome constituents in surface water as they frequently exceeded water quality objectives established by the RWQCB.

The quality of surface water in reservoir storage has been the focus of limnological investigations initiated in 1974 by the District. The program involves ongoing limnologic monitoring of Anderson and Lexington Reservoirs, and a water chemistry study of Calero Reservoir. Goals include identification of contamination sources and the impact of land use changes on both water quality and reservoir operation. In addition, the Calero Reservoir study will indicate treatment requirements at the future Santa Teresa Water Treatment Plant (District, 1984).

The quality of local surface water influences its eventual use for artificial recharge. Water quality concerns in the artificial recharge program stem from relatively high sediment content in imported water. Turbidity is managed by bypassing flows with very high turbidity, use of settling ponds, and flocculation with alum. Recharge basins are scraped periodically to remove fine silts which tend to impede the infiltration of water into ponds.

Imported Surface Water. Currently, imported surface water consists of water from the Hetch-Hetchy system and the South Bay Aqueduct. Hetch-Hetchy water originates in the Yosemite area and is generally considered to be high quality (SCVWD, 1983). Giardia, the single-celled organism which is the most common cause of waterborne gastroenteritis, has been detected in water supplies of several communities receiving water from Hetch-Hetchy watershed. The State Department of Health Services has recommended filtration for removal of Giardia, and filters are likely to be installed for a portion of the water within the next two years. This water is pre-treated (pH adjustment and chlorination) at four facilities before it is distributed to individual purveyors in Santa Clara Valley. THM concentrations range between 60 - 70 ppb (DOHS, 1984).

Surface water from the South Bay Aqueduct originates in mountain watersheds of northern California and passes through the Sacramento/San Joaquin Delta before being diverted to State Water Project canals. In contrast to most surface water in the Santa Clara Valley, the Sacramento and San Joaquin Rivers usually are sodium bicarbonate types and ocassionally are sodium chloride types. This reflects the influence of irrigation return flows (USGS, 1971). The quality of this water varies considerably on a seasonal and, at times, on a daily basis depending on seawater intrusion in the delta, flooding, and the presence of tannin, algae, and bacteria. Most of this water is treated at Penitencia and Rinconada water treatment plants of the District.

Treatment measures include coagulation, flocculation, filtration, sedimentation, chlorination, and chloramination. Table VI-1 summarizes quality parameters of raw water received at the two water treatment plants. Fluctuation in quality of raw water does not follow consistent trends, thereby creating a challenge in maintaining high quality treated water. The DWR is cooperating with the District to indicate quality changes in water before it reaches the treatment plant (Haden, SCVWD, 1986, pers. comm.).

Table VI-1.
Raw Water Quality Parameters
at Rinconada and Penitencia Water Treatment Plants, 1985.
(SCVWD, 1986).

Parameter	1985 Range (mg/l)
Turbidity	1 - 150 NTU
pH	7.4 - 8.9
Temperature (C)	7.9 - 26.9
Color	3 - 18 color units
Odor	1.0 - 2.0 T.O.N.
Alkalinity (as $CaCO_3$)	54 - 184
Hardness (CaCO3)	73 - 237
TDS	168 - 344
Sodium	28 - 56

One water quality problem at the treatment plants is the presence of Trihalomethanes (THM's). THM's, such as chloroform, are formed when halogens (ie., chlorine, bromine, or iodine) react with naturally occurring organic matter, such as humic substances, present in raw water. The use of chlorine in water treatment can lead to the formation of chloroform, a suspected carcinogen (Snoeyink and Jenkins, 1980). The drinking water standard for total THM's is 100 ppb (yearly average). In 1981 THM concentrations averaged as high as 106 ppb in at the Rinconada plant.

As an alternative to chlorination, post-chloramination (after filtration), a treatment process which combines chlorine with ammonia, has been employed in recent years at Rinconada to reduce THM's. Table VI-2 lists total THM levels during 1985 at the two District treatment plants. It is interesting to note that THM levels at the Penitencia plant were typically lower than those at the Rinconada plant even though chloramination was not employed at Penitencia. The difference in plant design is responsible; Rinconada has an upflow clarifier which increases the contact time of incoming water with sludge, while the Penitencia plant has a flow through design.

In further response to the THM problem, the District has proposed a pilot treatment plant which will employ ozonation for THM precursor removal. Ozonation is a treatment process with many benefits including reductions in chemical use, chlorine application, and THM production.

Table VI-2.
Total Trihalomethane Concentrations
Measured at Penitencia and Rinconada Treatment Plants
During 1985 (SCVWD, 1986).

(Values in parts per billion)

Jan	Feb	Mar	Apr	May	Jun	Jul	Apr	Sep	Oct	Nov	Dec
RINCONADA											
52	53	54	58	48	36	69	100	56	94	56	80
PENITENCIA											
36	37	43	49	55	49	61	103	38	80	49	61

Pesticides, originating from irrigation return flows, are another surface water quality concern. Trace levels of pesticides have been reported in Delta water, including water released into the South Bay Aqueduct at the Clifton Court Afterbay (White Paper, 1984). At the Rinconada plant quarterly pesticide analyses are performed. To date, no pesticides have been detected.

GROUNDWATER QUALITY.

Groundwater Monitoring. In 1985, a new groundwater monitoring network was initiated by the District. The first annual sampling included 60 representative wells distributed across the three subbasins. Samples were analyzed for bacteria, minerals, metals, pesticides, and solvents. The program is designed to provide background concentrations of these constituents. In addition, local water purveyors periodically run analyses of organic and inorganic constituents, bacteria, THM's, and nitrates. The sampling frequency for VOC and nitrates undertaken by purveyors are listed on Table VI-3.

Table VI-3.
Frequency of Groundwater Testing by the Water Purveyors for VOC and Nitrates.

(DOHS, September 1986)

Purveyor	Source(s)	Test	Frequency
City of Cupertino	All Wells (2)	VOC	Annually
City of Gilroy	All Wells (6)	Nitrates	Weekly
	" "	VOC	Monthly
City of Milpitas	All Wells (2-standby)	VOC	Annually
City of Morgan Hill	All Wells (9)	Nitrates	Monthly
	" "	VOC	Annually
City of Mountain View	All Wells (5)	VOC	Annually
	Well #18	VOC	Monthly
	2 Wells	VOC	Quarterly
City of Palo Alto	All Wells (10-standby)	VOC	Annually
City of San Jose	All Wells (7)	VOC	Annually
Evergreen (Er)	ER (4)	VOC	Monthly
City of San Jose Alviso	All Wells (2)	VOC	Annually
City of Santa Clara	All Wells (27)	VOC	Annually
	2 Wells	VOC	Monthly
	4 Wells	VOC	Quarterly
California Water Service Company-Los Altos	4 Wells	Nitrates	Quarterly
	All Wells	VOC	Annually
	Hillview #10	VOC	Monthly
Great Oaks Water Co.	All Wells (13)	VOC	Annually
San Jose Water Co.	All Wells (112)	VOC	Biennially
	28 Wells	VOC	Quarterly-Monthly
	All Well Fields	VOC	annually
Redwood Mutual-Water Company	Springs (3)	VOC	Annually
	Wells (2)	VOC	Quarterly
Stanford University	All Wells (3 Standby)	VOC	Annually
City of Sunnyvale	All Wells (10)	VOC	Annually

-Continued-

Table VI-3, continued.
Frequency of Groundwater Testing
by the Purveyors for VOC and Nitrates.

Purveyor	Source(s)	Test	Frequency
San Martin Water Works	1 Well	Nitrates	Triennially
West San Martin Water Works	2 Wells	Nitrates	Triennially

General Chemical Quality and Trends. Groundwater is typically a calcium-magnesium bicarbonate type throughout most of the three groundwater subbasins. The sodium ratio increases in the confined zone toward the bay in Santa Clara Subbasin. TDS values are between 350-500 mg/l in the forebay in Santa Clara Subbasin and between 188-1280 mg/l in Coyote and Llagas Subbasins. Groundwater is often hard with typical hardness values greater than 200 mg/l. Native groundwater is generally high quality, although "some areas have a higher concentration of dissolved solids than desirable for the optimum quality of water for drinking." (Dunn, 1982)

In 1978-79, the DWR analyzed samples from 198 wells covering an area extending from immediately north of Coyote Narrows and southward into the Bolsa Subbasin (south of the Pajaro River). Hardness, sodium, total alkalinity, chloride, nitrate, boron, TDS, pH, and specific conductance were measured. The distribution of sampling points was approximately two wells, one shallow and one deep, per square mile. During selection of candidate sampling wells, priority was given to those wells with existing water quality data, a complete driller's log, and water level information. Highlights of the results are contained in Table VI-4. The water quality results were compared to historical records, but no conclusive trends were identified. The study unsuccessfully attempted to differentiate water quality in the shallow and the deep aquifer. Only a limited number of wells with construction data were available, and many of these wells were completed at intermediate depths or were screened in both shallow and deep aquifers.

A regional study, comparable to the DWR study, has not been conducted for Santa Clara Subbasin. However, several generalizations are apparent regarding groundwater quality from routine monitoring of wells in that basin. Seawater intrusion has modified groundwater quality as indicated by the progressive shift to a sodium bicarbonate type groundwater approaching San Francisco Bay. In addition, elevated TDS values (500-1000 mg/l) are reported along the base of the Diablo Range in Santa Clara County (Webster, 1972). Elevated boron concentrations in the Penitencia Creek alluvial fan are attributable to boron in Penitencia Creek which recharges groundwater in this region. Boron in this region is geologic in origin.

Table VI-4.
Groundwater Quality of Coyote and Llagas Subbasins
(DWR, 1980).

	Ionic Concentration in mg/l		
	Low	Average	High
Alkalinity	89.	240.	654.
Boron	0.0	0.2	2.8
Chloride	9.7	44.5	563.
Hardness	101.	299.	948.
pH	7.4	8.1	8.7
Nitrate (NO3)	0.0	28.7	210.
Sodium	5.9	44.2	222.
TDS	188.	488.	1280.
Specific Conductance (umhos/cm)	348.	736.	2140.

GROUNDWATER CONTAMINATION*

Sources and Types of Contamination. Groundwater contamination in the Santa Clara Basin was first documented in 1972 when nitrate concentrations in excess of drinking water standards were reported (USGS, 1972). More recently, attention has focused on industrial solvents contaminating groundwater with the discovery in 1981 of a major underground tank leak at Fairchild Camera and Instrument Company in South San Jose. In response to that incident, subsequent investigations uncovered 21 leaking solvent storage tanks in the Santa Clara Subbasin (Oliveri, 1983). As of September 1986, there were about 106 industrial sites with ongoing (ongoing or pending) contamination investigations (SFRWQCB, October 1986).

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* In this section groundwater "contamination" by solvents implies that **detectable** levels are present. As such, levels may or may not be in excess of Federal drinking water standards or state action levels.

In general, there are several mechanisms which can be involved in groundwater contamination including:

- **Surface infiltration** (spills, lagoons, application of agricultural chemicals, irrigation return flows, recharge from contaminated surface water).
- **Subsurface infiltration** (underground storage tanks, pipelines, landfills, septic systems, injection wells).
- **Interaquifer exchange** (natural gradients, hydraulically induced gradients, abandoned or improperly sealed wells, multi-aquifer development, and exchange with connate water).
- **Seawater intrusion.**

The mode of contamination at specific sites in the Santa Clara Valley has not been documented in each case. Thus far emphasis has been placed on contamination from leaking underground storage tanks or piping. Over 550 contamination incidents (solvent and fuel leaks) have been related to this mechanism, resulting in the delineation of at least 26 contaminant plumes. The types of contaminants associated with the storage tanks typically consist of fuels or volatile organic compounds used as industrial solvents. Table VI-5 lists the 20 most frequently found contaminants, many of which are ubiquitous in industrial processes. The use of trichloroethylene (TCE) has been reduced to minimize the potential hazard of this chemical in the Santa Clara Valley (SFRWQCB Appendix, 1985).

Table VI-5.
Most Frequently Found Groundwater Contaminants in the Santa Clara Subbasin (SFRWQCB, 1985).

Contaminant (Abbrev.)	Number of sites with contaminant
1,1,1-Trichloroethane (TCA)	64
Trichloroethylene (TCE)	60
Trichlorofluoromethane (Freon)	53
Tetrachloroethylene (PCE)	49
Xylene	47
1,2-Dichloroethylene (DCE)	44
Toluene	44
Trichloromethane (Cloroform)	41
1,1-Dichloroethane (DCA)	39
1,1-Dichloroethylene (DCE)	39
Ethyl benzene	36
Methylene chloride	33
Acetone	29
Benzene	27
Isopropyl alcohol (IPA)	20
Methyl ethyl ketone (MEK)	17
Vinyl chloride	15
Phthalate esters	14
1,2,4-Trichlorobenzene (TCB)	12
Phenol	10

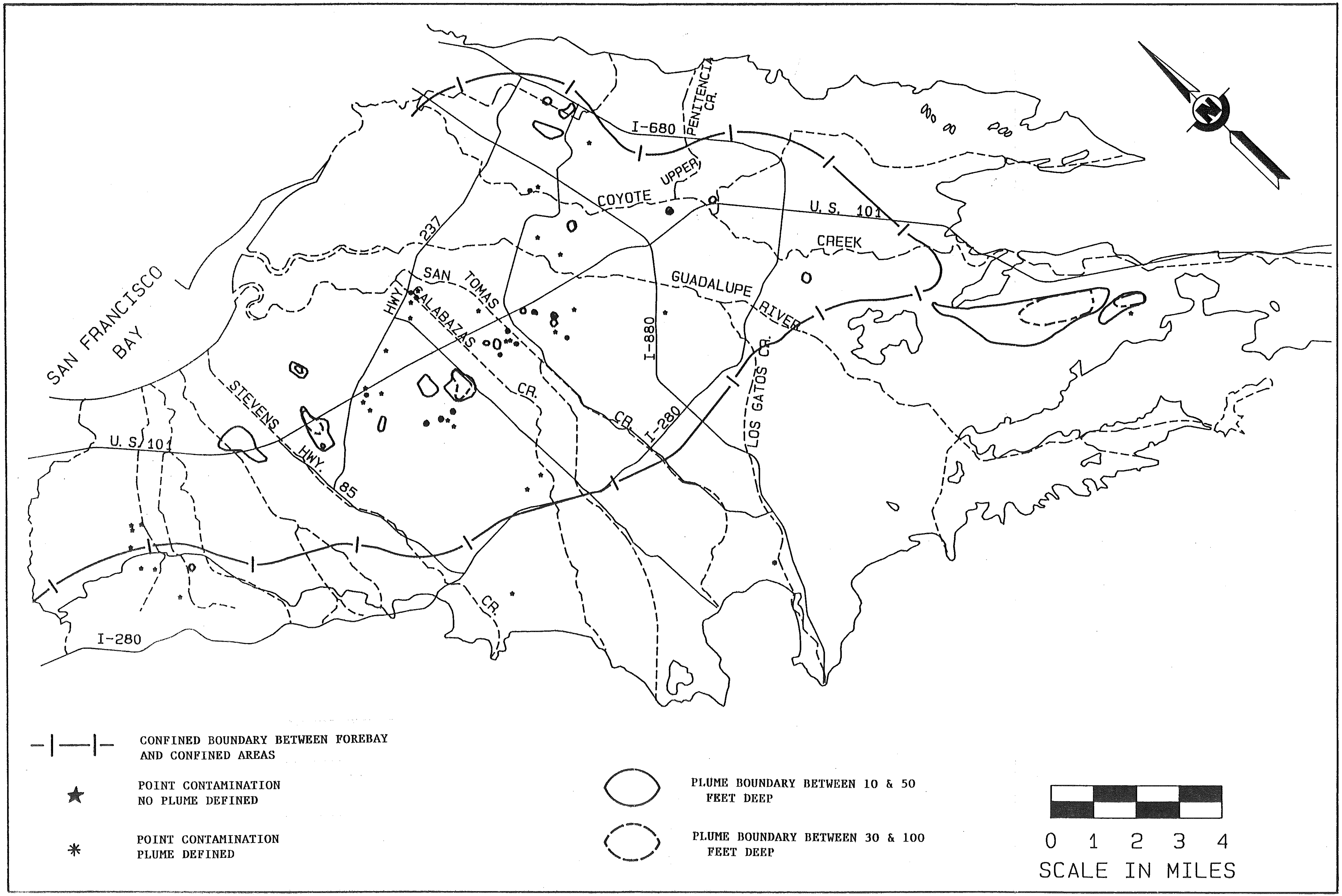
Oliveri (1983) concluded that the leakage may not exclusively relate to the storage tanks themselves; rather, from "improper storage, handling, or disposal above ground " (ie. overfilling of tanks, emptying of hoses from delivery trucks, or storage in leaky barrels). This implies that many other facilities handling hazardous materials which do not necessarily have leaking tanks, may have contaminated soils or groundwater. Some tank site contamination is thought to represent illegal dumping of hazardous materials. Sixty locations in Santa Clara County are sites of improper disposal of hazardous materials.

In addition to industrial solvents, gasoline has also been a problem in Santa Clara Valley. As of April 1987 there were at least 489 fuel leak sites under investigation.

The application of agricultural chemicals, more specifically nitrogen fertilizers, have been responsible, in part, for elevated nitrate concentrations measured in groundwater in Llagas Subbasin (Brown and Caldwell, 1981). Another source of nitrate contamination may be septic system effluent.

The potential for contamination from landfills has been the subject of investigation by the Association of Bay Area Governments under contract with EPA. There are no hazardous waste landfills in the County. There are 11 permitted Class III sanitary landfills, which were found to have a low potential for groundwater contamination. One exception to this is the Singleton Road landfill, near San Jose, which has contaminated groundwater with organic compounds (DOHS, September 1986).

Extent of Contamination. Figure VI-1 illustrates the location of contaminant plumes, point contamination in shallow groundwater (between 10 and 50 feet deep and also between 30 and 100 feet), and soil contamination in the Santa Clara Subbasin. These map includes only solvent sites and does not include sites with gasoline contamination. In some multiple source areas, small separate plumes appear to have coalesced into single plumes. The overlap between 30 to 50 feet deep exists because some shallow aquifers begin


SAN FRANCISCO BAY
I-680
PENITENCIA CR.
UPPER
COYOTE
U.S. 101
CREEK
237
HWY
SAN TOMAS
CALABAZAS
GUADALUPE
RIVER
I-880
CR.
CR.
I-280
LOS GATOS CR.
STEVENS
HWY.
85
U.S. 101
CR.
I-280
CONFINED BOUNDARY BETWEEN FOREBAY AND CONFINED AREAS
POINT CONTAMINATION NO PLUME DEFINED
POINT CONTAMINATION PLUME DEFINED
PLUME BOUNDARY BETWEEN 10 & 50 FEET DEEP
PLUME BOUNDARY BETWEEN 30 & 100 FEET DEEP
0
1
2
3
4
SCALE IN MILES
N

Location of Contaminant Plumes in Groundwater
between 10-50 and 30-100 feet deep

Figure VI-1

at a depth of 30 feet and extend below 50 feet. VOC contamination reported in seven wells in Llagas Subbasin near Gilroy is not indicated on this map.

A few public water supply wells have been found to be contaminated. These fall under the jurisdiction of seven purveyors, including San Jose Water Company, City of San Jose, City of Santa Clara, City of Gilroy, Redwood Mutual, California Water Service Company, and Great Oaks Water Company. Purveyors operating wells with low levels of contamination are sampling their wells for VOC on a monthly to quarterly basis.

The plume boundaries shown on Figure VI-1 enclose regions where the concentration of contaminants is greater than detection limits, which is generally 1 ppb for VOC's. At best, this map is a preliminary indicator of actual plume dimensions; plumes are still poorly defined, especially in deeper groundwater, with the exception of the IBM and Fairchild plumes (south of Highway 280 between Coyote and Canoas Creeks). Contamination at these two sites has been under intensive investigation and is currently in remedial phase.

Within the confined area contamination has been restricted to the shallow groundwater with three notable exceptions. First, contamination has been detected at levels to 502 feet in Mountain View. Migration through conduit wells is the suspected mechanism; an investigation of the site is underway. Second, two wells perforated below the confined layer in Santa Clara are contaminated by unknown sources. Third, seven San Jose Water Company wells and four City of San Jose wells may have been contaminated by the IBM plume. These wells are located close to the southern extent of the confined zone in what is known as the Evergreen Area.

In comparison with the confined area, relatively few contaminant plumes have been identified in the forebay. However, the largest plume present in the subbasin is in the forebay, and at least 12 wells in Campbell have low levels of contamination. Investigations in Campbell are currently in progress (Hurley-SFRWQCB, 1986, pers. comm.).

As expected, groundwater contamination in the forebay is not restricted to shallow depths. Three plumes in the forebay, shown on Figure VI-1, extend down to depths of 30 to 100 feet. Deeper portions of the unconfined area have been affected by contamination in at least one reported case. A 505 foot public water supply well located in a residential area in Los Altos has levels of carbon tetrachloride (CCl_4) ranging between 6 -7 ppb. The source of contamination is unknown (Ling-DOHS, 1986, pers. comm.). Currently, well head treatment has been applied to reduce CCl_4 concentrations to less than 1 ppb.

The percentage of the basin that is contaminated was estimated by measuring the 26 plumes in Figures VI-1. In addition, the area of 37 other sites labeled as "point contamination-no plume defined" or "point contamination - plume defined", indicated by solid circles and circles enclosing X's, respectively, was estimated to be 10 acres each. This is based on the size of existing small plumes, which are generally between 8 to 12 acres. The SFRWQCB has determined that the average plume length is over 900 feet (RWQCB, 1986). If the width is one-half to one-third of this length, the 10 acre assumption is reasonable. A summary of plume sizes is listed on Table VI-6.

Based on the total of 3748 acres for the contaminated area and a dimension of 144,000 acres for the total Santa Clara Subbasin, 2.6 % of the subbasin surface is underlain by contaminated groundwater. With the exception of three plumes in the forebay, currently defined plumes are in the shallow groundwater of the confined area. However, the total area of plumes overlying the confined area (1898 acres) was only slightly larger than plumes in the forebay (1850 acres). These areas represent 5.4% of the total confined zone area (excluding the area where chloride concentrations are greater than 100 mg/l) and 1.9 % of the forebay area, respectively.

Table VI-6.

Summary of Contaminant Plume Sizes
(measured from Figure VI-1)

Area in acres		Number of Plumes
1 - 10		4
11 - 50		12
51 - 100		3
101 - 500		6
500 - 1000		0
> 1000		1
TOTAL = 3748 Acres*	TOTAL	26

* This total includes the acreage of the additional 37 sites with plumes not yet defined, assuming an area of 10 acres each.

The volume of contaminated groundwater was also estimated according to the measured areas, average plume thickness, and an assumed porosity. According to SFRWQCB, the average plume depth is 55 feet. Assuming an average depth to the water table of 15 feet, the average plume thickness would be 40 feet. The porosity of the aquifer was assumed to be 30%, representing a reasonable estimate for a sand and gravel aquifer.

The total volume of contaminated groundwater is approximately 45,000 acre-feet. Comparison of these figures with basin storage between 10 and 110 feet (1,220,000 acre-feet) indicates that 3.8% of the shallow aquifer is contaminated. None of the plume maps show data below 100 feet, so the percentage of the deep aquifer that is contaminated cannot be estimated. However, given the existence of only ten contaminated wells in the deep aquifer (Table VI-7) the percentage certainly would be considerably less than that in the shallow aquifer.

Contamination Levels. Levels vary widely, from less than 1 ppb to greater than 1000 ppb, with the highest concentrations measured in monitoring wells at the site of contamination. In general, levels in monitoring wells tend to fall into the high range (>1000 ppb) or low range (<100 ppb) categories with concentrations often one to two orders of magnitude over state action levels. On the other hand organic chemicals measured concentrations measured in public water supply wells, which are listed on Table VI-7, generally have been significantly lower and generally below DOHS action levels. One exception is a California Water Service Company well in Los Altos, where carbon tetrachloride has been found. San Jose Water Company operates wells with contamination below action levels on a standby basis, and the California Water Service Company well is treated to below action level prior to delivery.

Table VI-7.
Summary of Organic Compounds Found in Large Water Systems

(modified after DOHS, October 1984, August 1986,
and September 1986,)
(see end of table for explanation of symbols and abbreviations)

State Well Number and Name	Water System	Depth (ft)	Chemicals	Max. Conc (ppb)	Source
Open Wells					
06S/02W-29M02M (Well 110)	CWS-Los Altos	700 #	CCL4	10	unknown
08S/01E-10G03M (Blossom Hill 4)	San Jose Water Co.	406 #	TCA	2	unknown
08S/01E-10G04M (Blossom Hill 5)	" "	406 #	TCA	1	unknown
08S/01E-10G03M (Bryan 4)	" "	400 #	PCE	1	unknown
07S/01E-22H04M (Tully Well #1)	" "	780 +	TCA CFC-113	1 1	IBM
07S/01E-22H05M (Tully Well #2)	" "	800 +	TCA CFC-113	1 3	IBM
07S/01E-22H06M (Tully Well #3)	" "	756 +	TCA CFC-113	1 3	IBM
07S/01E-22H07M (Tully Well #4)	" "	850 +	TCA CFC-113	1 1	IBM
06S/01W-29P19M (well 20-02)	City of Santa Clara	660 +	Cis 1,1-DCE	.5	unknown
07S/01W-05P02M (well 24)	" "	770 +	CFC-113 TCA	7 .5	unknown
07S/01E-26B02M (Evergreen 2)	City of San Jose	355 +	TCA CFC-113	3 7	IBM

-Continued-

Table VI-7 continued.

Summary of Organic Compounds Found in Large Water Systems

State Well Number and Name	Water System	Depth (ft)		Chemicals	Max. Conc (ppb)	Source
		Open Wells (continued)				
07S/01E-26A01M (Evergreen 3)	City of San Jose	380	+	TCA CFC-113	2 2	IBM
07S/01E-26B10M (Evergreen 4)	" "	400	+	TCA CFC-113	7 3	IBM
07S/01E/-26B11M (Evergreen 5)	" "	400	+	TCA	7	IBM
11S/04E-06B01 (Well 1)	Gilroy	760	#	TCA PCE	1.1 1.4	unknown
11S/04E-06D01 (Well 2)	"	406	#	TCA PCE	1.0 2.3	unknown
11S/04E-06H01 (Well 3)	"	346	#	TCA PCE	1.6 1.2	unknown
11S/04E-06P01 (Well 4)	"	302	#	TCA PCE	0.5 0.61	unknown
11S/04E-08C02 (Well 6)	"	550	#	TCA PCE	0.5 0.79	unknown
11S/04E-32N02 (Well 7)	"	410	#	TCA PCE	0.5 1.2	unknown

-Continued-

Table VI-7 continued.

Summary of Organic Compounds Found in Large Water Systems

State Well Number and Name	Water System	Depth (ft)	Chemicals	Max. Conc (ppb)	Source
		Standby Wells			
09S/01W-17F02M (Well 1)	Redwood Mut.	60	TCE CHCl3	3 3	unknown
07S/01W-26R02M (Ridgley 1)	San Jose Water	870 #	TCA	3	unknown
07S/01W-26R03M (Ridgley 2)	" "	846 #	TCA	3	unknown
07S/01W-26R04M (Ridgley 3)	San Jose Water Co.	850 #	PCE	1	unknown
07S/01W-27P03M (San Thomas 2)	" "	673 #	PCE	1	unknown
07S/01W-27P05M (San Thomas 5)	" "	940 #	TCA	1	unknown
07S/01E-26D02M (Senter 1)	" "	528 +	TCA	3	IBM
07S/01W-27M01M (Springfield 1)	" "	520 #	PCE	0.5	unknown
		Closed Wells			
08S/01E-12P01 (Well #2)	Great Oaks Water Company	366 #	TCA	2.6***	IBM
08S/01E-12D10 (Well #8)	" "	318 #	TCA	17	IBM
? (Well #13)	" "	302 #	TCA	100	Fairchild
07S/01W-35C03M (First St. 1)	S.J. Water	438 #	TCA 1,1-DCE	11 .4	unknown

-Continued-

Table VI-7 continued.

Summary of Organic Compounds Found in Large Water Systems

State Well Number and Name	Water System	Depth (ft)	Chemicals	Max. Conc (ppb)	Source
		Closed Wells (continued)			
07S/01W-35C02M (First St. 2)	S.J. Water	819 #	TCA $CHCL_3$ $CHBrCl_2$ 1,1-DCE	6 6 1 2	unknown
07S/01W-35C01M (First St. 3)	" "	946 #	TCA 1,1-DCE PCE CFC-113	23 2 1 1	unknown
08S/01E-01P02 (Well #1)	Rancho Santa Teresa Mobile Home Park	250	TCA CFC-113	4 3	IBM
? (Well #2)	" "	219	TCA CFC-113	7 7	IBM
?	Magic Sands Mobile Home Park	? #	TCA CFC-113	2 1	IBM
?	Carribbee Mobile Home Park	? ?	CFC-113 TCA	0.5 0.5	IBM or Singleton Landfill

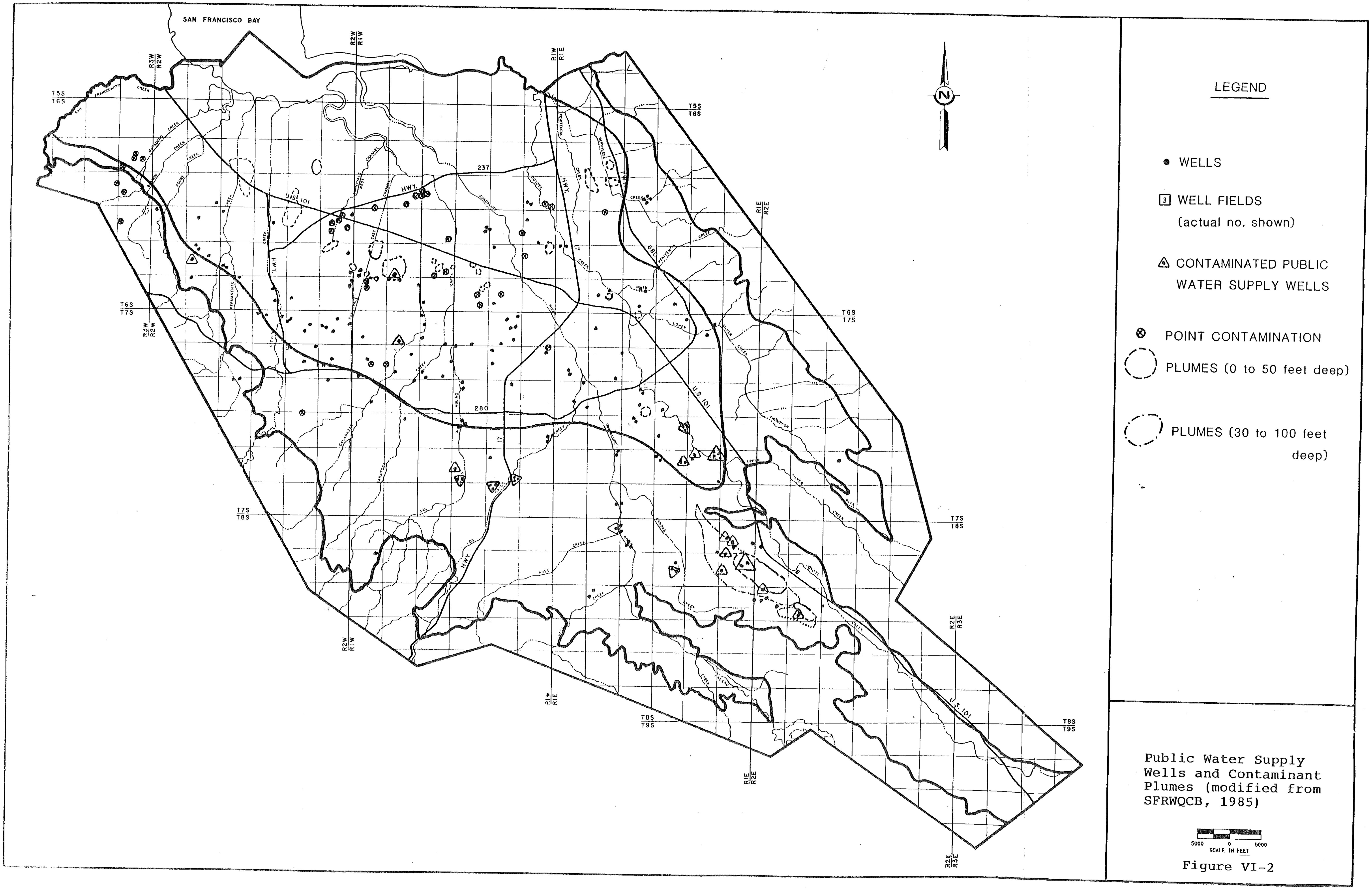
CFC-113 Freon 113.
CCl4 Carbon tetrachloride
See Table VI-5 for other chemical abbreviations.

? Information regarding state well number or depth is unknown.
+ Well is perforated below the aquitard in the confined area.
# Well is located in the forebay.
++ Concentration ranges between non-detectable and the number listed on the table.
*** Great Oaks well #2 is currently operational, with non-detectable levels of contaminants (Krajewski-Great Oaks Water Company 1986 pers. comm.).

Significance of Contamination. In terms of volume, the amount of water that is contaminated is relatively insignificant compared with the total volume of groundwater that is available in the Santa Clara Subbasin. However, the location of contaminant plumes near existing water supply wells and the hydrogeologic potential for migration between the two sites suggests that adverse impacts are possible unless careful monitoring and management of the groundwater resources are followed.

Contamination has affected at least 94 water supply wells (38 large public water supply wells, and 56 private wells) (DOHS, 1986). This represents 14.7% of the total public water supply wells (258) and 4.6% of the private wells (1205). As of 1987, ten public water supply wells had been closed due to contamination, while eight additional wells are restricted to "standby" status (see Table VI-7). Standby wells are operated during peak demand periods or for emergency purposes. Only one public water supply well was ordered to be closed; all other wells were closed voluntarily. Some 20 wells with levels of contaminants below state action levels are in service. For comparative purposes, in 1984 four public water supply wells were closed, four were on standby, and eight wells were operational with low levels of contamination (DOHS, 1984).

The public water supply wells and existing contaminant plumes are illustrated in Figure VI-2. Only wells that are contaminated with VOC's are indicated on this figure. Many



Public Water Supply Wells and Contaminant Plumes (modified from SFRWQCB, 1985)

Figure VI-2

of these wells are in the forebay along Coyote, Los Gatos, and San Tomas Aquino Creeks and Guadalupe River. As previously mentioned, wells in the Campbell area are currently under investigation.

The distance of existing wells from plumes was measured; results are summarized on Table VI-8. A total of 38 wells are between 0 and 1 mile from existing plumes. Out of the eleven wells identified as occurring within plumes, nine have actually been contaminated with the remaining two deep wells in the confined area apparently unaffected by contamination in the shallow aquifer. There are at least 20 additional wells that are known to be contaminated, but are not listed on Table VI-8 because they have not been related to a specific source or plume.

The vast majority of the public water supply wells are in the confined area, situated north of Highway 280, between Highways 85 and 17. The plumes in this general area are situated north of the wells along Highway 101 (see Figure VI-2). The average depth of the wells in this area is over 500 feet, which is 400 feet below the maximum depth of contamination. However, many wells are probably screened at shallower intervals.

Although site specific investigations would be needed to evaluate the susceptibilty of individual wells to contamination from plumes, geologic cross-sections are available in this region (DWR, 1975) from which several generalizations can be drawn regarding this 400 foot interval.

Table VI-8.

Measured Distance Between Public Water Supply Wells and Nearest Contaminant Plumes.

Radius (miles)	Number of Wells Within Radius
0	11
0 - 0.25	9
0.25 - 0.5	8
0.5 - 1.0	10
Total	38

A thick sequence of clay with infrequent thin layers of sand is present in the area underlying the highest density of plumes (along Highway 101). Accordingly, deep aquifers would have some protection from plumes present in the shallow aquifer. However, several sections in this region have a relatively high number of abandoned wells (i.e., greater than 16 wells per section). Moving progressively south toward the area with the highest density of wells, significant sand lenses are present within the clay deposits. The lenses are approximately one-quarter to over one mile long and between 10 to 100 feet thick. The lenses do not appear to be hydraulically connected. However, this region potentially has a higher degree of permeability than the plume area along Highway 101. This implies that contamination occurring upgradient from these wells could, over time, affect the quality of water supply wells.

Groundwater contours, shown on Figure II-8, indicate that regional groundwater flow directions in the confined area are strongly influenced by pumpage. Cones of depression modify the otherwise normal discharge toward San Francisco Bay. The pattern of groundwater contours is dynamic, varying from year to year depending on rainfall and pumping patterns; however, there are consistent cones of depression surrounding Mountain View, Sunnyvale, San Jose, and Santa Clara. The major zone of contamination appears to be near, but not within, the major cone of depression in the San Jose area. Other cones of depression between Mountain View and Sunnyvale, on Figure II-8, overlap the contaminated zone. However, locations are probably not meaningful as plumes in the confined zone are largely restricted to the shallow groundwater zone, and pumpage occurs below the major aquitard. Directions of groundwater flow in the shallow zone are poorly understood because regional water levels there are not measured. Based on the observation stated above regarding more permeable sections of the confined zone, pumping in the deep zone potentially could cause vertical transport of contaminants in the shallow zone.

Section VII

GROUNDWATER QUALITY PROTECTION AND CLEANUP

There are three primary programs in the Santa Clara Valley designed to prevent groundwater contamination and to protect groundwater quality. These programs are the Hazardous Materials Storage Ordinance, an ongoing fuel tank investigation program, and a well sealing program. Development of the programs was prompted by the discovery of a major underground tank leak in South San Jose in 1981 (see Section VI). Heightened awareness of the vulnerability of groundwater to contamination has paved the way for the development of several early warning systems and preventive mechanisms.

At sites of existing groundwater contamination, remedial measures are administered by the Regional Water Quality Control Board (RWQCB) and the Department of Health Services (DOHS). The remedial measures are designed to prevent the further spread of contaminants and to remove contaminated groundwater. Although industries have voluntarily complied with regulations, cleanup is a relatively slow process and will be ongoing at most sites for several years.

CURRENT GROUNDWATER PROTECTION PROGRAMS

Hazardous Materials Storage Ordinance (HMSO). In 1982-1983 a task force representing governments, businesses, and communities drafted a model Hazardous Materials Storage Ordinance. The ordinance is designed to protect groundwater from future storage tank leaks through a program of improved tank storage and source monitoring. Facilities that store hazardous materials and/or hazardous wastes above or below ground are subject to this regulation. The model ordinance was adopted, with modifications, across the county by nearly all local jurisdictions in 1983. Table VII-1 lists the cities that have adopted the ordinance. The specific agencies supervising the ordinance are city fire departments, county fire protection districts, or the county health department (Morrell and Elliott, 1986).

Table VII-1.

Organization of Individual HMSO Programs
(from Morrell and Elliott, 1986)

Individual Municipal HMSO Implementation

Campbell
Gilroy
Milpitas
Morgan Hill
Mountain View
Palo Alto
San Jose
Santa Clara
Sunnyvale

County Central Fire Protection District HMSO Implementation

Cupertino
Los Gatos

County Health Department HSMO Implementation

Los Altos
Los Altos Hills
Monte Sereno
Saratoga
Unincorporated Areas

The ordinances require secondary containment of all new hazardous storage facilities. Acceptable containment includes a second tank wall or a lined vault around the tank to catch leaks. This requirement does not apply to existing facilities; however, existing facilities with single-walled tanks must be tested for leaks and retrofitted with monitoring systems. Monitoring options include tank testing, inventory controls, groundwater sampling, and vadose (unsaturated) zone vapor sampling. All facilities must apply for a storage permit and submit a comprehensive management plan; included in the plan are a map of storage facilities and sewers, and a list of the amounts and types of hazardous materials stored. In addition, facility owners must assume responsibility for preventing, reporting, and cleanup of leaks. The HMSO defines civil and criminal penalties for violations.

A recent survey was conducted to evaluate the status of the ordinances in the county (Morrell and Elliott, 1986). A summary of the costs, cost recoveries, and schedules is listed on Table VII-2. On a county-wide basis the total annual cost is over two million dollars. The percentage of this total recovered from permit fees ranges from 14 to 100% for the individual programs. Overall an average of 56% of were recovered, with the balance of over $900,000 made up by local revenues. The target dates for full implementation vary; however, all programs should be in place by 1990. Over 4,700 facilities have applied for permits, representing 85% of the total number of anticipated facilities; 87%

Table VII-2.

HSMO Implementation, Time Lines, Resource Commitments, and Cost Recovery. (Morell and Elliott, 1986)

Program	Target for Complete Implementation	Personnel	Annual Budget ($1,000)	%Budget From Fees	$ Unmet ($1,000)
Campbell	6/87	1.0 *	$ 90	33%	$ 60
County Fire	1/87	1.0	$ 63	39%	$ 39
Gilroy	8/86	1.0	$ 36	50%	$ 18
Milpitas	1988	2.0	$130	50%	$ 65
Morgan Hill	1990	0.5	$ 22	30%	$ 15
Mt. View	annual ++	3.0 *	$200	83%	$ 15
Palo Alto	(completed)	3.3	$205	96%	$ 8
San Jose	10/86	6.0	$467	43%	$267
Santa Clara	(completed)	3.1 *	$258	100%	$ 0
Sunnyvale	1987	3.9	$497	39%	$303
County Health	1987	3.0**	$192	14%	$165
TOTAL COUNTYWIDE		27.8 *	$2,160	56%	$955

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* Hazardous materials personnel only; excludes time by other fire personnel performing joint/fire code inspections.

** County Health is only program with no access to outside support; all others receive at least occasional assistance from other fire personnel.

++ Mountain View collects fees, based on hazard class and volume range, and issues permits on an annual basis. As of August 1986, 86% of 1985 permitees had filed renewal applications.

(4,102) of these have been granted permits. Since the HMSO's have existed, at least 1,438 tanks have been removed which is roughly 28% of the total single-walled tanks. The survey indicated that the HMSO's are effective, but in practice have been more difficult and more expensive to implement than originally expected.

A database management system, designed to store the monitoring information generated from the HSMO, has been proposed by the SCVWD (SCVWD, November 1986). The purpose is to provide an efficient, systematic way for regulators to manage and evaluate the monitoring data. In particular, the database would ease the workload of regulators by providing the following features:

1. A systematic method for collection of information.
2. A listing of site characteristics, well characteristics, monitoring devices, and companies used for monitoring, etc.
3. A listing of companies which are deliquent.
4. A listing of wells where latest readings indicate nearby tank leaks.
5. A graph of the historical background water quality readings from a particular well and/or groups of wells.
6. A listing of other wells within a specified area and associated information.

Ongoing Fuel Tank Investigations. Investigation of fuel tank leaks can prevent groundwater contamination if the fuel can be contained, treated, or removed before reaching groundwater. As of May 1987, there were 489 known sites of gasoline contamination in Santa Clara County; over 100 of these involve groundwater contamination. Fuel leaks that are initially reported to the Regional Board are evaluated so that appropriate recommendations regarding monitoring and cleanup can be made to the responsible party. Shortages in technical staff at the Regional Board have resulted in delays in the cleanup of known leaks. The SCVWD has facilitated the evaluation process by hiring four staff members to be trained by the RWQCB. These persons will address fuel leaks in Santa Clara County.

Well Sealing Program. In recognition of the threat posed to groundwater quality from abandoned wells that may serve as conduits between shallow and deep aquifers, the SCVWD initiated a well sealing program. In 1984, $800,000 was approved by the District's board of directors for the program. The cost for sealing an individual well averages $2500 and ranges up to a maximum of $12,000. The anticipated benefit includes lowering the risk of additional groundwater contamination occurring via conduit wells. Accordingly, this reduces the potential for exposure of the population to hazardous chemicals in groundwater and reduces aquifer cleanup costs.

In order to focus on the wells most likely to result in groundwater contamination, the District staff noted the location of existing contaminant plumes (Figure VI-1) and designated the areas one to two miles around the plumes as high priority regions for well sealing. Inactive wells within these regions were located from well permit records and field reconnaissance. Wells located on sites that were either under development or ordered to close due to contamination were excluded from consideration. This exclusion was made in recognition that the cost of well closure should be incurred by the developer in the former case and by the polluter in the latter case.

During the first phase of the program, 160 wells were targeted and letters were sent to respective owners for permission to proceed. Only five owners refused to have their well sealed. During ongoing phase two, 270 additional wells have been targeted representing an expansion of the contaminated areas of concern. Out of this number, 13 owners refused while an additional 21 wells did not have owners. To date, 144 wells have been sealed representing 33% of the total wells targeted. The sealing procedure entails removal of pumps or any other obstruction, measurement of the well depth, and filling the well with cement grout.

In late 1985, the District received an additional $200,000 from the Regional Board for an abandoned well inventory. This program consists of researching active and inactive wells in the vicinity of the 7 listed and 12 proposed Superfund sites in Santa Clara Valley. Relevant information regarding these wells--such as location, depth, and perforation interval--is entered into a computer database. This study is ongoing with anticipated follow-up to include sealing of wells that could act as conduits for contaminants.

Since the District well sealing program has been in place, a county-wide ordinance (85 - 1) has been approved. This ordinance, effective in 1986, requires owners to seal abandoned wells that potentially could contaminate groundwater. Also, by order of the RWQCB, industry is looking for abandoned wells in the vicinity of contaminated sites.

GROUNDWATER CLEANUP

The RWQCB, DOHS, and EPA are the principal agencies regulating groundwater cleanup in Santa Clara Valley. The South Bay Groundwater Contamination Enforcement Agreement, developed in 1985, established an enforcement relationship among the three agencies. The RWQCB is the lead agency in most of the cases. Typically, cases are referred by RWQCB to DOHS when soil contamination is involved or when the source of groundwater contamination is unknown. The State Superfund is available through DOHS. Currently, RWQCB is overseeing cleanup on 118 sites; 5 of these have been referred to DOHS. The EPA has the ability to provide funding for investigation and cleanup through the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly referred to as Superfund.

In recognition of the overlap in administration of cleanup activities, the South Bay Groundwater Contamination Task Force was formed in 1984 to coordinate efforts among agencies. The task force consists of representatives from RWQCB, DOHS, SCVWD, City of Sunnyvale, Santa Clara County, and EPA. The task force provides a forum for open discussion, and an opportunity for agency representatives to better understand and coordinate groundwater protection and cleanup activities.

Typically after contamination is first discovered, exploration and monitoring is required by RWQCB to determine the level and extent of contamination. In these cases RWQCB requires interim remedial action and potential conduit studies to assess the potential for vertical migration. Immediate response actions, such as tank removal, may also be required. If public water supply wells are found to be contaminated, the state action levels are used to determine if wells should be closed. However, if public water supply wells are not involved, no definitive standards are used to determine if soil or groundwater cleanup is required. In 1968 the State Water Resources Control Board Resolution No. 68-16 established a non-degradation policy for state waters. Under this policy RWQCB and DOHS require owners of facilities to conduct feasibility studies which evaluate the migration and exposure potential to groundwater contamination. Based on these studies the agencies establish appropriate cleanup levels on a case by case basis.

Based on the results of feasibility studies, remedial action may be required. Alternatively, if the current levels of contamination do not mandate mitigation, continued monitoring of soil and groundwater may be required. If remediation is necessary, RWQCB requires facility owners to propose acceptable methods for cleanup to meet appropriate cleanup levels and has statuatory authority to insure compliance. The DOHS plays a similar role, but can dictate the method of cleanup to the facility owner. Remedial measures for soil contamination have included soil aeration, vacuum extraction, and soil excavation. Once removed, the contaminated soil typically is hauled to a Class I facility.

Remedial measures for groundwater contamination have included groundwater containment and extraction. Containment to prevent the spread of contamination has been accomplished by modifying hydraulic conditions with pumping wells or a combination of impervious barriers and pumping wells. In one case a slurry wall was installed around a groundwater contamination source to isolate it from surrounding groundwater. The RWQCB does not routinely determine potential pumpage conflicts between extraction wells and production wells; however, in cases where there may be a potential conflict, they have asked industry to evaluate the situation.

In order to discharge extracted groundwater legally, industries must obtain Waste Discharge Requirement (NPDES) permits issued by the RWQCB. If necessary to meet water quality discharge levels, determined by the RWQCB on a case by case basis, groundwater is treated by carbon adsorption, whereby activated carbon adsorbs organic compounds, or by air stripping, which drives off volatile organic compounds. After treatment groundwater is discharged into streams, surface drainage channels, or to sanitary sewers.

Status of Cleanup Activities. As of September 1986 there were over 100 cases involving groundwater and/or soil contamination in Santa Clara County (SFRWQCB, October 1986). Some 70 of the facility owners have begun site characterization studies, while an additional 28 have completed these studies. Remedial action has been undertaken by 47 facility owners. A total of 51 cases (43%) require soil removal; 28 of these cases have been completed. Groundwater extraction/containment has been required in 61 cases (51%), with only one completed. As of September 1986, 39 Waste Discharge Requirement permits have been issued, with 9 sites not in compliance. In terms of meeting regulatory deadlines, 65 (55%) sites are running behind schedule, 15 (13%) are on schedule, and 10 (8.4%) are ahead of schedule. Overall, compliance has taken place on a voluntary basis thus requiring minimal enforcement action.

Costs of Cleanup Activities. Industry in Santa Clara Valley has spent over $ 100 million in groundwater cleanup and improved storage tank facilities since 1981 (DOHS, 1986). The SFRWQCB budget for the investigation of groundwater contamination sites during 1986 was over $977,000. Funding for oversight of cleanup work on sites listed on the National Priorities List is provided by the EPA Superfund through the Multisite Cooperative Agreement. This budget is consumed primarily by program management (13%), site management system (8%), and enforcement (70%).

The site management system contains all the specific information from contamination sites including site description, nature and extent of contamination, impact on public and private wells, case status, enforcement and other regulatory actions, and site milestone reports. The system facilitates tracking of individual site progress. Enforcement encompasses all the investigative case work and the issuance of Waste Discharge Requirement permits required of industries discharging groundwater as part of cleanup. Figures indicating funds spent by the DOHS for groundwater cleanup in Santa Clara Valley are not readily available; however, the State Superfund operating budget is $10 million per year.

Groundwater Cleanup and Groundwater Supply. During 1986 groundwater pumpage at the IBM and Fairchild sites totaled 15,840 acre-feet. Pumpage volumes at all other cleanup sites totaled just over 200 acre-feet in 1985. For comparative purposes, groundwater lost due to pumpage at all contaminated sites (16,040) is about 28% of the natural yield for Santa Clara Subbasin (58,200 acre--feet per year), and 9% of public and private pumpage for 1985 (181,300 acre-feet). To date there has been no reported interference between groundwater extraction wells and municipal water supply wells. However, groundwater levels in the vicinity of IBM and Fairchild extraction wells have reportedly declined. This condition apparently produced lowered water levels in Great Oaks wells but not to a degree whereby pumpage was adversely affected.

SECTION VIII

VALUE OF GROUNDWATER BASIN

Santa Clara County has many sources of water, including local groundwater, local surface water, and water imported through the Hetch-Hetchy Aqueduct, South Bay Aqueduct, and San Felipe Division of the Central Project Valley . Only a small proportion of local surface water conserved in the Santa Clara Subbasin is used directly; most is percolated to the groundwater basin through the District's artificial recharge facilities. In the South County, local surface water is distributed for agricultural purposes, or is recharged and later pumped for agricultural, industrial, or domestic purposes.

Most imported surface water is treated and distributed directly; however, approximately 15% was recharged to the groundwater basin in 1985 for recovery by private and municipal wells. Until completion of the Santa Teresa Water Treatment Plant, a major proportion of water imported through the San Felipe Division will be recharged.

Accordingly, Santa Clara County's groundwater basin not only supplies local groundwater but also serves a central role in the indirect supply of surface water. In this section the benefits and costs of the current use of the groundwater basin are discussed. Alternatives to use of the groundwater basin are considered and costs are quantified when available.

BENEFITS OF CURRENT SYSTEM OF GROUNDWATER USE

The current system of groundwater development includes use of local groundwater yield and artificial recharge of surface water (see Figure IV-2). Development of the local groundwater yield intrinsically involves taking advantage of the basin as a water source, its large storage volume, the treatment afforded by percolation through basin sediments, and the conveyance or distribution of water supply through groundwater flow. Use of the basin in the artificial recharge program intentionally takes advantage of the storage, treatment, and conveyance benefits. The following discussion includes definition not only of each benefit, but of the particular portion of the groundwater basin which is significant in providing the benefit.

Water Source. Current use of the groundwater basin includes development of the natural yield, which amounts to 107,800 acre-feet per year, distributed among subbasins as follows: Santa Clara--58,200; Coyote--4,400; Llagas--45,200. The natural yield includes subsurface inflow from rocks surrounding the basin, as well as infiltration from uncontrolled streamflow, rainfall, and irrigation.

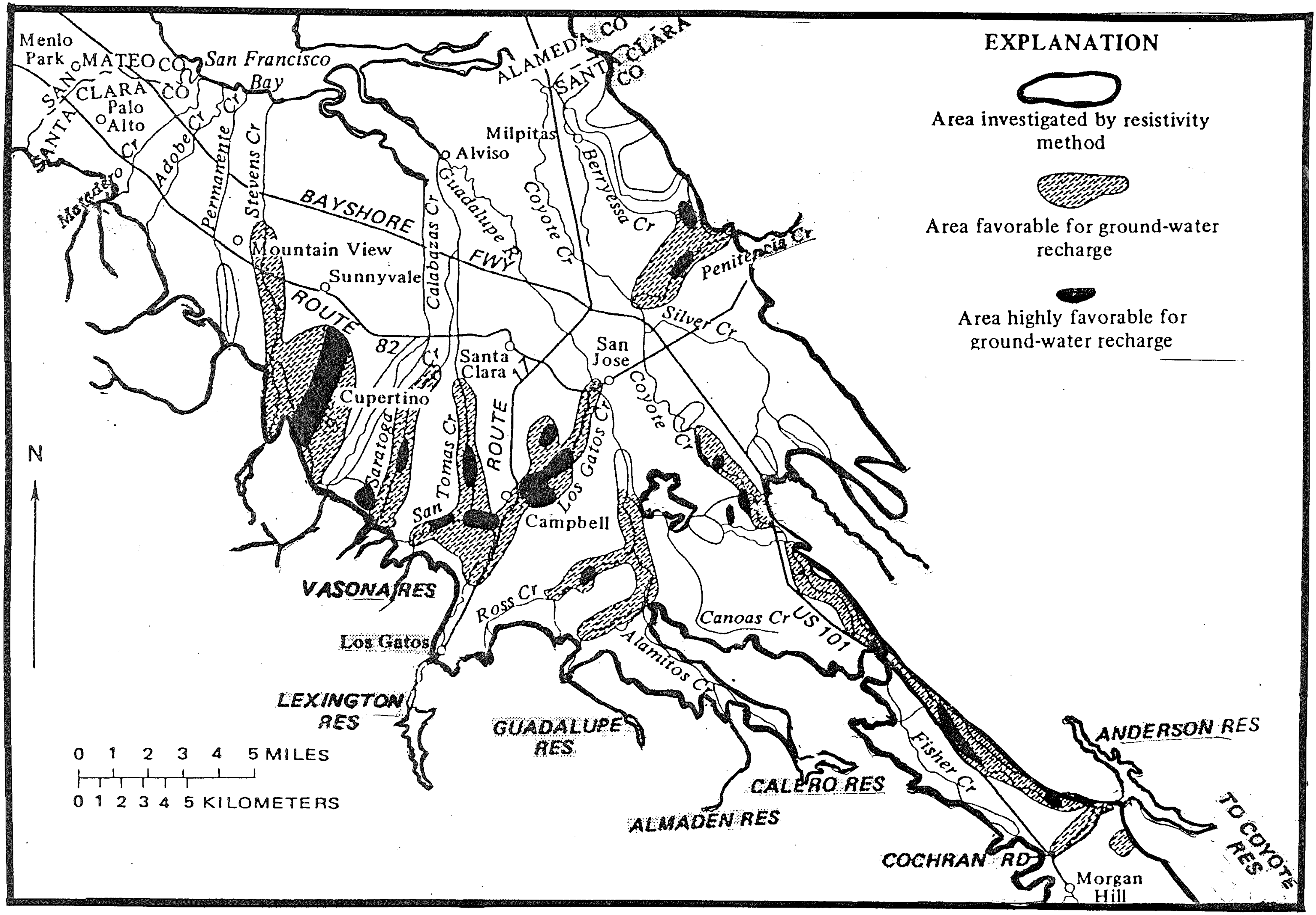
Natural recharge through infiltration occurs throughout the groundwater basin, but is most significant in the forebay. Factors influencing the rate of infiltration in any particular area include topography, permeability of soil and sediments, depth to groundwater, and land use. Figure

VIII-1 is based on hydrogeologic investigations that indicate favorable and highly favorable areas for groundwater recharge. All of these areas are located within the forebay and along the major streams. It should be noted that stream channels are recharge areas of particular importance, not only because of their permeable sediments, but also because of the availability of surface water for recharge.

Figure VIII-2 shows land use in the Santa Clara and Coyote Subbasins, boundaries of the forebay, and favorable recharge areas. The land use categories that are most favorable for recharge are open space and residential. In these areas, a significant proportion of the land surface remains permeable. In addition, a significant proportion of the area is irrigated, either for agricultural or landscaping purposes. Commercial and industrial land uses generally involve dense development, with a major portion of the land area either covered with buildings or pavement. Consequently, little of the ground surface is available for infiltration. Only two major commercial/industrial areas are located in the forebay--one in the southeast along Coyote Creek and another in the west near Calabazas Creek.

The forebay zone and land use in the South County were illustrated in Figure III-4. Most of the area is occupied by irrigated agriculture, open space, and residential land uses. Commercial and industrial land uses are located in Morgan Hill, San Martin, and Gilroy.

Figure VIII-1



Areas Favorable for Groundwater Recharge, Santa Clara County
(Helley and LaJoie, 1979 after Page and Wire, 1969)

Storage. The groundwater storage volume available in Santa Clara County amounts to 3,776,000 acre-feet, distributed among subbasins as follows: Santa Clara--3,225,000; Coyote--76,000; Llagas--475,000. This storage volume, which extends to an average depth of about 300 feet as defined in DWR Bulletin 48, is considerable. For example, the total capacity of major surface water reservoirs in Santa Clara County amounts to less than 200,000 acre-feet, or only about 6% of the groundwater storage. In times of drought, surface storage is quickly depleted, while groundwater storage can be relied on to supply water for extended periods. In addition, surface water storage is more subject to evaporation losses and disasters such as earthquake damage.

The distribution of municipal water supply wells in the Santa Clara and Coyote Subbasins is shown in Figure VIII-3, as are the locations of artificial recharge facilities. The approximate areas of the recharge facilities' most significant hydrologic influence are indicated by dashed lines. These areas were defined by overlaying the locations of recharge facilities on recent (1984) water table contour maps. Recharged water flows with the groundwater gradient, generally toward the valley center and production wells. Typically, municipal wells are perforated between 400 and 800 feet deep.

The distribution of private wells, location of artificial recharge facilities, and boundaries of forebay in the Santa Clara and Coyote Subbasins are shown in Figure

VIII-4. Generally, private wells are less than 150 feet deep.

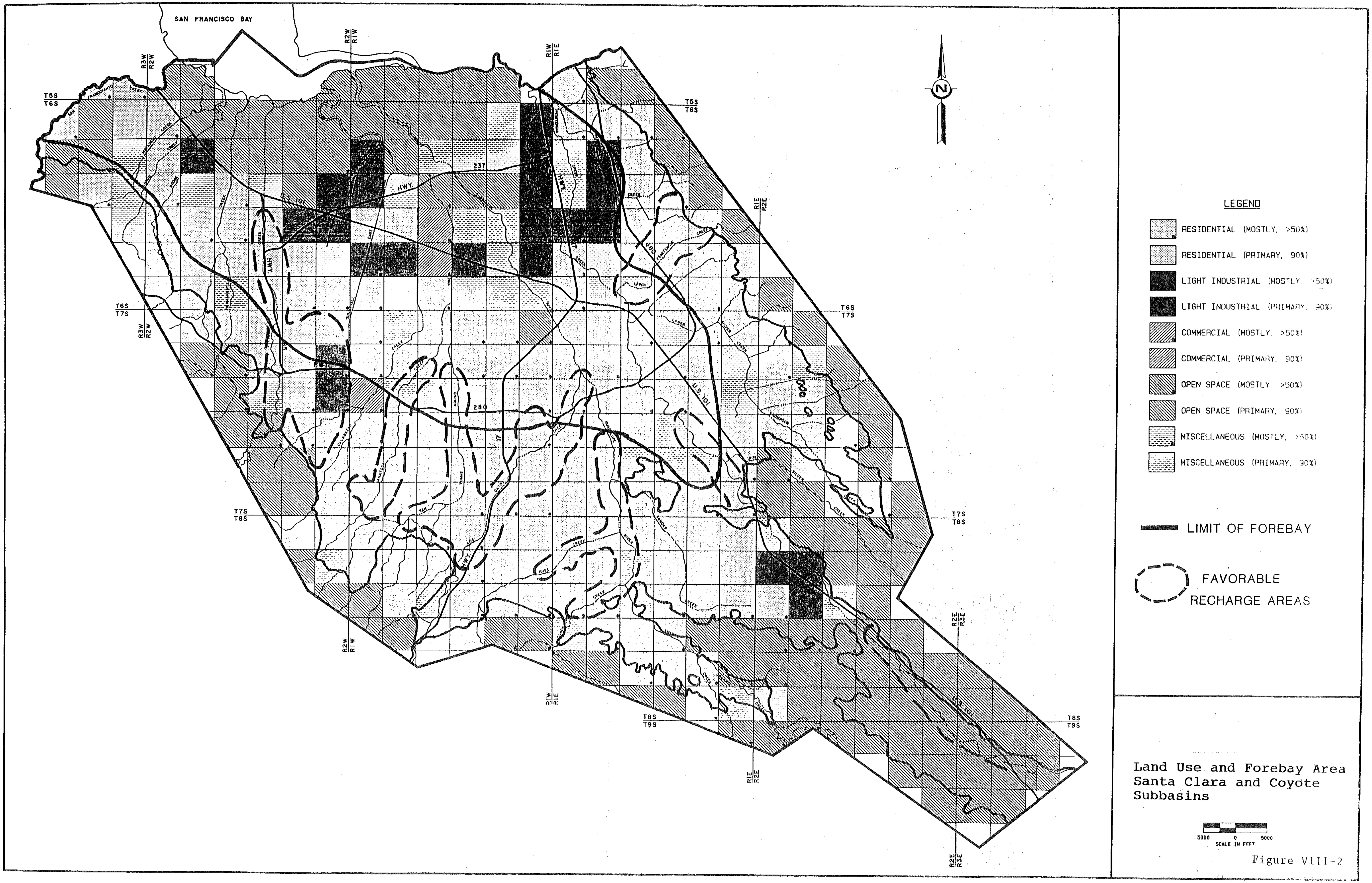
The location of municipal wells, artificial recharge facilities, and the forebay zone in the Llagas Subbasin are illustrated in Figure VIII-5. As indicated, municipal wells are clustered in the vicinity of Morgan Hill and Gilroy, and generally are perforated between the depths of 150 and 500 feet. The distribution of private domestic and irrigation wells, which account for a considerable proportion of local pumpage, is not known.

Treatment. Water treatment afforded by movement through the sediments of the groundwater basin includes removal of sediment and pathogenic organisms, and reduction of some pollutants. Treatment occurs within the unsaturated zone immediately below the artificial recharge facilities and within the saturated aquifer between the facilities and production wells that recover the water.

Distribution. Groundwater, flowing along a hydraulic gradient from areas of high water levels to areas of low levels, effectively distributes itself to pumping wells. The distribution in the artificial recharge program occurs between the recharge facilities and production wells.

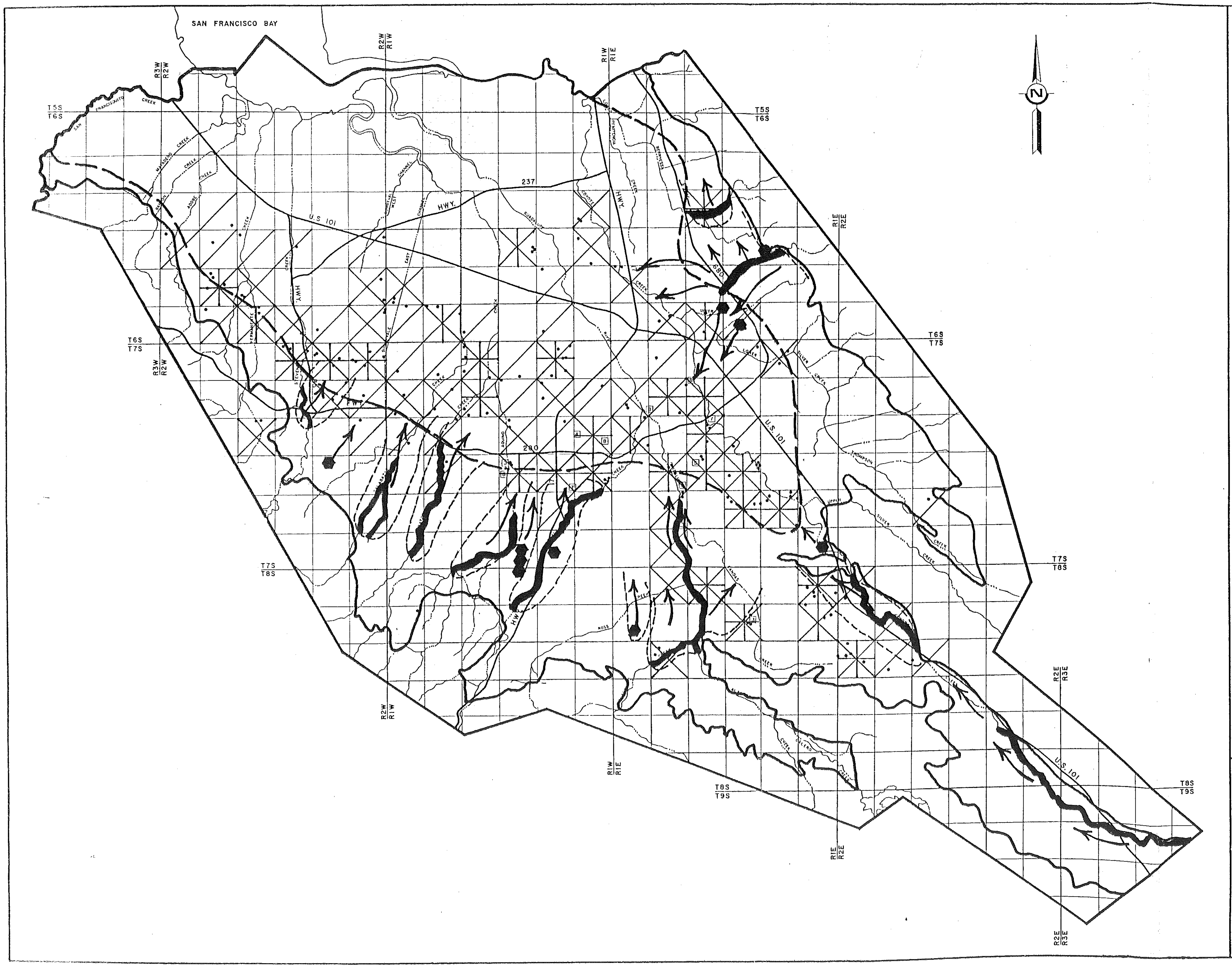
COSTS OF CURRENT SYSTEM OF GROUNDWATER USE

The costs of the current system of groundwater use are incurred by a number of parties, including Federal, State, and local agencies; private companies; and local consumers.



Land Use and Forebay Area Santa Clara and Coyote Subbasins

Figure VIII-2



LEGEND

● WELLS

[3] WELL FIELDS. (actual no. shown)

SECTION with 1 WELL

SECTION with 2 WELLS

SECTION with 3 WELLS

SECTION with 4 or MORE WELLS

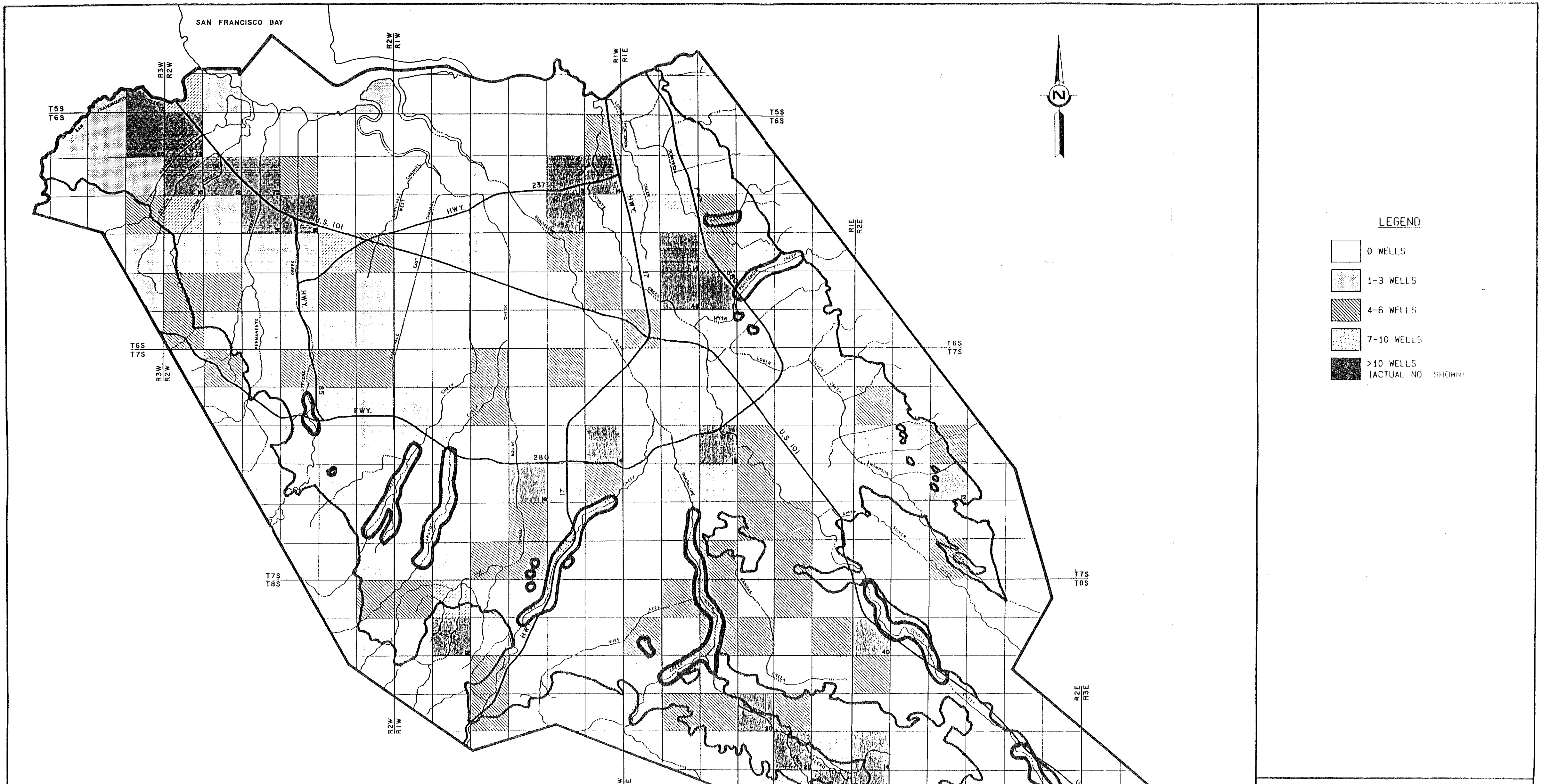
⬢ ARTIFICIAL RECHARGE PONDS

ARTIFICIAL RECHARGE along STREAM

Municipal Wells and Artificial Recharge Areas, Santa Clara and Coyote Subbasins

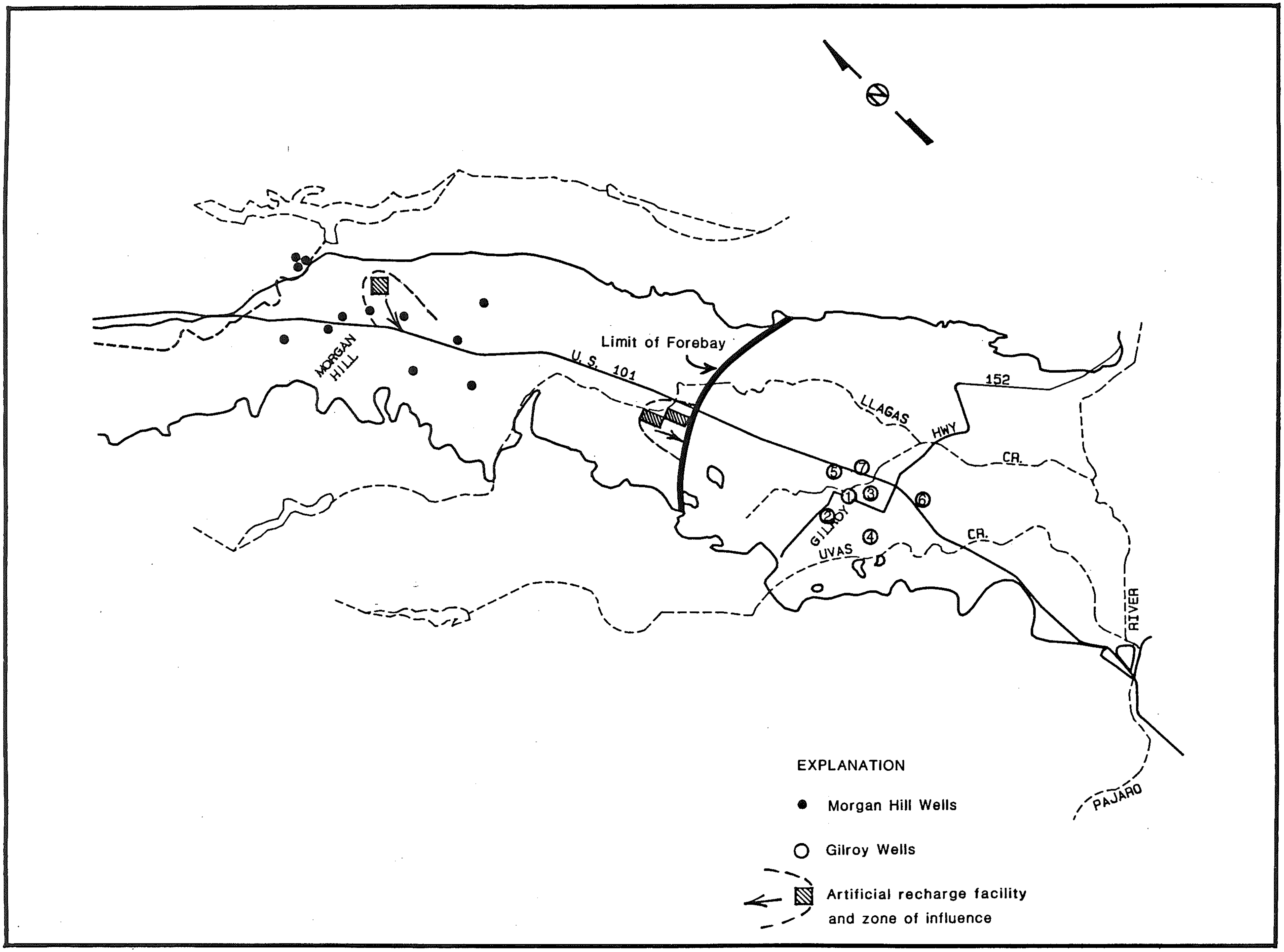
5000 0 5000
SCALE IN FEET

Figure VIII-3



Distribution of
Private Wells and
Recharge Facilities
Santa Clara and
Coyote Subbasin

Figure VIII-4



Distribution of Municipal Wells, Recharge Facilities, and Forebay Area, South Santa Clara County

Figure VIII-5

In this discussion costs are subdivided in terms of the purveyor's costs, which include groundwater development and local management costs; costs accrued by the Santa Clara Valley Water District for basin-wide management; and costs associated with maintenance of groundwater quality, including groundwater quality protection and groundwater cleanup. Costs also are incurred by individuals who develop groundwater for their own use; these include the costs of installing a well and pump, pumping, and maintenance.

Purveyor Costs. Principal costs of groundwater use incurred by local purveyors include the costs of installation of wells and pumps, pipelines, and other facilities; pumpage costs; operation and maintenance; water treatment (if any); monitoring; and administration.

Major cost items involved in installation of a large supply well include well siting, design and other engineering services; well casing, screen, and the pump; and well drilling and testing. These cost items vary considerably depending primarily on well size and design, so that capital costs for a municipal well can range from $50,000 to $250,000. Acquisition of land for a well site, and the cost of other facilities such as pipelines and pumping stations present additional capital costs.

The principal expenditure for operation and maintenance is the energy cost of pumpage. These costs also vary, depending largely on the efficiency of the pump, cost of energy (electricity), and pumping lift. As an example, pumpage costs among the various retailers during January 1987 in Santa Clara Valley, where pumping lifts range from 70 - 205 feet, is about $100 per acre-foot. General maintenance of a large well is about $1500 per year (Reichard and Bredehoeft, 1984; Todd Engineers, March 1986). Water treatment (if needed), monitoring of water levels and quality, and administration represent additional annual costs.

Costs to the water purveyors of groundwater development is variable; accordingly, evaluation of total costs would require a county-wide survey and analysis of purveyor budgets. Such an evaluation is beyond the scope of this study. However, it is possible to approximate the total cost through examination of retail water prices. Generally, the value of resources and the cost incurred in providing them are reflected in their market price, if they are traded on a competitive basis. However, it should be noted that water is not marketed competitively and that the California Public Utility Commission regulates private water companies. Therefore, retail water prices provide only a rough approximation of the value of water or the cost of providing that water.

Examples of retail prices for municipal and industrial water users are shown in Table VIII-1. The groundwater charge levied by the District has been subtracted from the retail price. This charge (pump tax) reflects a portion of the District's costs of basin-wide management, which are

Table VIII-1.

Retail Costs for Municipal and Industrial Water, 1986.

Purveyor	Purveyor Water Source	Total Retail Cost ($/ac-ft)	Retail Cost minus District Charge ($/ac-ft)
City of Morgan Hill	100% groundwater	$264	$264*
City of Gilroy	100% groundwater	$219	$219*
Great Oaks Water Company	100% groundwater	$321	$226**

* The cost does not include the District groundwater charge, which is not applied to the Llagas Subbasin. Capital costs of joining the water system are recovered through a one-time hook-up charge.

** These charges include water quantity charges, meter charges, and because Great Oaks is a private company, a fair return on investment.

passed on to the purveyor and subsequently to the retail customer. However, there is no direct relationship between the pump tax and the cost of basin management. This groundwater charge is discussed in a following section.

As indicated in Table VIII-1, retail water prices (excluding the District groundwater charge) range from $219 to $264/acre-foot. These prices roughly approximate the retailer's costs of providing groundwater.

District Costs. As discussed in Sections IV and V, the District is the agency with primary responsibility for management of groundwater resources. Therefore, the District operates an extensive artificial recharge program; monitors groundwater pumpage, levels, and quality; and conducts a variety of groundwater investigations and programs.

Groundwater quality management encompasses groundwater quality monitoring, major groundwater program areas (e.g. well sealing and enforcement of well construction standards) and special studies (e.g. salt water intrusion investigations). The total annual cost of these programs is about $3 million. The total annual expenditure on groundwater quantity programs, including water use measurements, groundwater level measurements, annual water balance reports, and special studies (e.g. percolation pond study and pumpage meter facility modification) is about $1.6 million.

Costs of the artificial recharge program in the Santa Clara Subbasin, which represents the major groundwater management effort in the basin, have been analyzed previously (Reichard and Bredehoeft, 1984). Principal costs involved in the program include: (1) water costs, (2) land costs, (3) construction of recharge ponds, (4) operation and maintenance of recharge ponds, and if needed, (5) construction, operation and maintenance of water conveyance and pumping facilities. These costs, reflecting 1982 prices, are summarized in Table V-2.

Groundwater Quality Control. Costs associated with maintenance of groundwater quality are incurred by Federal, State, and local agencies; private water purveyors; and private manufacturing companies that handle potential pollutants. The specific efforts involved in maintenance of groundwater quality are described in Section VII. Although some information on cost of individual projects is available, data are insufficient to assess total costs of groundwater quality maintenance.

Almost all groundwater quality control programs (and expenditures) were initiated in the 1980's. Many of these programs will continue in the future. In addition, it is probable that the number of contamination site investigations and cleanup programs will increase. As a consequence, costs of maintaining groundwater quality in the basin can be expected to increase in the future.

ALTERNATIVE WATER SYSTEMS

As indicated previously, use of the groundwater basin involves using the basin as a water source as well as for storage, treatment, and transport of water. The groundwater basin annually provides an estimated natural yield of almost 108,000 acre-feet of water. In addition, more than 100,000 acre-feet of water are artificially recharged each year*. However, costs are incurred in continuing use of the groundwater basin, and can be expected to increase. In addition, concern exists that the future use of the basin could be impaired by contamination. In recognition of this possibility, alternative water sources and water systems for storage, treatment, and distribution are considered.

Increased Water Import. Imported water comprises a major source of water to Santa Clara County at present, and is expected to provide additional water in the future.

The District has considered increasing the import of the South Bay Aqueduct Water beyond the current entitlement (See Section IV). As described in the 1975 Master Plan, the aqueduct has an excess capacity of 22,000 acre-feet/year. This amount of water could be developed through two alternative projects: one involving construction of a pipeline, pump station and new storage reservoir on the east side of the Santa Clara Valley to transmit water from the

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* Artificial recharge in 1986 amounted to about 136,000 acre-feet for the entire basin except recharge areas along Llagas and Uvas Creeks.

Santa Clara terminus; and another entailing construction of a pipeline parallel to the aqueduct from Mission Tunnel to the Santa Clara terminus. Unit capital costs (in 1973 dollars) amount to $52 and $24/acre-foot for the two alternatives, respectively. The cost to purchase the water was estimated at $51/acre-foot, bringing the total unit costs to $103 and $75/acre-foot respectively. Since 1975, capital and water costs have increased substantially; therefore, costs for these alternatives will be much higher than originally estimated. Also, as mentioned in Section IV, the State Water Project may not be able to supply the 22,000 acre-feet of water because the current firm yield of the project is less than its total contractual obligation.

In contrast, the Federal Central Valley Project has developed water supplies in excess of its contractual obligations and its present Delta export capacity (US Bureau of Reclamation and California DWR, July 1985). This supplemental water supply, amounting to 405,000 acre-feet, could be purchased by the State Water Project and conveyed or "wheeled" through State facilities. An agreement for joint operation of the Central Valley and State Water Projects, signed in November 1986, commits the Federal and State governments to begin negotiating toward an agreement for such wheeling arrangements. The wheeling program will result in increased diversion from the Delta and concomitant environmental impacts, which will be assessed when alternative wheeling arrangements are known.

Another possible source of additional imported water is the Hetch-Hetchy system. Excess water is not available at present due to conveyence limitations; however, the possibility has been explored of raising O'Shaugnessy Dam to increase the yield of the system. Increasing the height of the dam by 50 feet would provide an additional water yield of 100,000 acre-feet/year (Coffey, 1987).

Because water demand in the City of San Francisco itself is not increasing, this water would be available to other municipal customers. However, the possibility of implementing this project is remote until a pressing need for additional domestic supply can be documented. No such need is foreseen by the City of San Francisco until after 2020. In any event, public debate over the plan will be intense because the water originates in Yosemite National Park.

Santa Cruz County. In the District's 1975 Master Plan, the possibility of importing surface water from Santa Cruz County was considered briefly. Although some Santa Cruz County streams apparently have surplus water, this alternative was not pursued because of anticipated political opposition, environmental concerns, and high costs.

Increased Capture of Local Surface Water. The 1975 Master Plan includes evaluation of nineteen possible projects to increase the developed yield of local watersheds through construction of new reservoirs or enlargement of existing facilities. Only one of these projects, enlargement of Calero Reservoir, is under active consideration.

Yields of the nineteen possible projects ranged from 240 to 22,100 acre-feet/year, with a total of 105,000 acre-feet per year or more. Unit costs ranged from $77 to more than $500 per acre-foot (1973 dollars).

Several of the possible projects were deemed infeasible at the time because of small yields, high costs, engineering problems, or environmental impacts.

Wastewater Reuse. Wastewater reclamation and reuse, currently a minor source of water in Santa Clara County, could be significantly increased. Potential uses include agricultural and landscape irrigation, power plant cooling, paper manufacturing, dust control, street cleaning, and groundwater recharge. Wastewater reuse is feasible, as indicated by the numerous existing projects across the state. Reuse entails some environmental benefits, most notably that discharge of wastewater to San Francisco Bay would be reduced. However, health concerns exist, particularly where wastewater reuse involves human contact or where wastewater is recharged to aquifers developed for domestic water supply. Although health impacts apparently are minimal, given operation with ordinary vigilance, public reaction to wastewater reuse usually is cautious.

One of the best known wastewater reclamation projects is Water Factory 21 in Orange County. This plant, completed in 1976, receives secondary wastewater and provides advanced treatment, as well as reverse osmosis demineralization to one-third of the flow. The resulting water, which is recharged to local aquifers, meets both Federal and State drinking water standards. Costs in 1981 to provide advanced treatment to 15,100 acre-feet amounted to $239/acre-foot, while costs for demineralization of about 5,000 acre-feet were an additional $273/acre-foot (Cline, 1982).

In 1982 the Orange and Los Angeles Counties (OLAC) Water Reuse Study summarized 45 proposed wastewater reuse projects and their costs (OLAC, April 1982). These projects ranged in size from 290 to 35,000 acre-feet per year, with costs ranging from $40 to $1950/acre-foot (1985 dollars). Most projects involved landscape irrigation and would reuse between 500 and 3000 acre-feet/year at a cost of $300 to $500/acre-foot. If the top ten projects in terms of cost effectiveness were implemented, the combined yield would approximate 27,000 acre-feet/year at a weighted average cost of $200/acre-feet.

Santa Clara County produces more than 122,000 acre-feet/year of treated wastewater (Kahrl, 1979), most of which meets secondary standards, and has existing plant capacity to treat 210,000 acre-feet/year. Only a small proportion currently is reused. Therefore, an ample wastewater supply exists for agricultural, landscape irrigation, and other uses, although additional treatment may be required. The District's 1975 Master Plan considered wastewater reuse, concluding that reclaimed wastewater could be developed for agricultural irrigation at costs of about $85/acre-foot. A reclamation project in Palo Alto sponsored by the SCVWD indicated much higher operating costs based on a number of years of operation. A project in Gilroy also sponsored in part by the SCVWD showed higher costs.

Urban Water Conservation. As shown during the 1970s drought, a crisis can provoke significant changes in water use habits and dramatic declines in water consumption. However, urban water conservation often is not regarded as a long-term alternative to developing water supply. Long-term conservation relies not only on changes in water use habits but also on structural changes such as improvements in water system efficiency, use of water-saving appliances and fixtures, and changes in landscaping.

A prime example of urban water conservation is that of Tucson, Arizona, a city which currently depends on a dwindling groundwater supply. Significant water conservation efforts implemented in 1976 included a dramatic water rate increase, a progressive restructuring of water rates, and the "Beat the Peak" public information campaign designed to spread out water usage during summer peak periods (Metzger, 1984). These efforts were supplemented subsequently by the "Slow the Flow" campaign to reduce indoor water use, and by amendments to the municipal building code intended to encourage installation of water-saving fixtures.

Population and water use data shown in Table VIII-2 indicate results of the Tucson water conservation efforts. Per capita water use and municipal groundwater pumpage peaked in 1973-74 following years of increase. With the water conservation efforts, per capita water use and municipal groundwater pumpage declined significantly. Per capita water use in 1978-79 was only 72% of 1973-74 levels, while pumpage declined to 81% of the former level despite an increase in population. Subsequently, per capita water use rebounded; this rise plus population growth resulted in an increase in municipal pumpage. However, effects of conservation are still evident; if per capita use had rebounded to 204.6 gpd, then an additional 17.5 mgd of groundwater would have been pumped in 1981-82.

Table VIII-2.

Population and Water Use in Tucson, Arizona

(Martin, et al., 1984).

Year	Population	Municipal Pumpage, mgd	Per Capita Water Use, gpd
1973-74	369,000	75.4	204.6
1978-79	396,000	60.8	147.5
1981-82	447,000	74.0	165.6

The City of San Jose is sponsoring the "Wastewater Flow Reduction Program" to reduce indoor water use. The goal is to achieve 10% reduction in wastewater by 1995. Estimated costs of the program will be $15 million while the benefits will be $115 million.

Transfer from Agricultural Areas. Another alternative source is water transferred from agricultural areas. This water could be made available as a result of conservation efforts by agricultural water districts or through purchase of agricultural lands and their appurtenant water rights. Likely agricultural regions for such transfers include nearby areas such as the South Santa Clara Valley, Hollister Valley, and Watsonville area, as well as the Central Valley. In California the legal status of water transfers is not clear. In addition, political opposition can be expected from rural areas, where concerns exist that sale of irrigated lands could undermine local economies.

Desalinization. Saline water from San Francisco Bay could be desalinized for drinking purposes. Several desalinization techniques, including distillation, reverse osmosis, and freezing, are technologically feasible and have been used to provide limited amounts of water in arid or water-short isolated areas. However, costs of desalinization are high; estimated costs to desalinize 12,000 acre-feet of water per year in Santa Barbara County amounted to $1,091 per acre-foot (Fowler, December 1984). In addition, disposal of waste brines would be difficult.

Storage, Treatment and Distribution. As indicated earlier, the groundwater basin currently provides storage, treatment, and distribution for the natural yield of the basin plus that for artificial recharge. An alternative system to provide these same benefits would involve surface reservoirs, water treatment plants, and pipeline distribution systems.

In their 1984 analysis, Reichard and Bredehoeft evaluated the costs of providing storage, treatment, and water conveyance for the approximately 100,000 acre-feet of water that is artificially recharged each year in the Santa Clara Subbasin. Their analysis is summarized in Table VIII-3. Costs were computed in 1982 dollars assuming a 40-year time period and two alternate discount rates of 7% and 10%. Results indicate that costs of continuing artificial recharge and subsequent groundwater recovery range from $39 million to $50 million, while the costs of the alternative surface system range from $286 million to $352 million. Therefore, the authors conclude that costs of continuing artificial recharge and groundwater use are much smaller than the surface alternative.

Table VIII-3.

Summary of Economic Analysis:
Costs of Artificial Recharge and An Alternative Surface Water System

(from Reichard and Bredehoeft, 1984).

	7 percent*	10 percent*
Discounted Costs of Artificial Recharge (million 1982 dollars)		
Land ($32,000/acre x 324 acres)	10.4	10.4
Operation ($480,000/year)	6.4	4.6
Pumping ($1,695,000/year)	22.6	16.5
Well Maintenance ($67,500/year)	9.5	7.2
Well Replacement	1.2	0.7
TOTAL	50.0	39.0
Discounted Alternative Costs (million 1982 dollars)		
Treatment		
a) Capital Cost	90.0	90.0
b) Fixed O&M ($2,034,000/year)	27.5	20.2
c) Variable O&M ($1,440,000/year)	19.2	20.2
Storage ($15,000,000/year)	200.0	146.6
Conveyance		
a) Capital Cost	14.7	14.7
b) O&M ($88,000/year)	1.2	0.9
TOTAL	352.0	286.0

* Discount rates

VALUE OF THE GROUNDWATER BASIN

In summary, Santa Clara County's groundwater basin provides water as a source, as well as storage, treatment, and conveyance benefits. Development of groundwater has entailed a significant capital investment in wells, pumps, pipelines, artificial recharge basins, and other facilities.

In addition, use of groundwater involves continuing costs to water purveyors, the District, private manufacturing companies, and water users. Costs to purveyors of providing groundwater are on the order of $200 to $260/acre-foot. Costs to maintain the quality of local groundwater are not known but are increasing.

In the event that protection of groundwater quality becomes technologically infeasible or too expensive, or that use of the groundwater basin is otherwise impaired, alternative surface water sources could be developed to replace the basin's groundwater yield. Alternative water sources include: increased water import, local surface water development, wastewater reuse, urban conservation, water transfer from agricultural areas, and desalinization. It is unlikely that any of these alternatives could replace the total groundwater yield with the possible exception of water transfer from agricultural areas. Most of the alternative sources that have been investigated in Santa Clara County and elsewhere yield less than 40,000 acre-feet/year, so that replacement of the entire groundwater yield would require development of several alternatives.

Costs of various water source alternatives versus the cost of using groundwater are not readily compared because the available data are incomplete and based on varying methodologies, different geographical areas, and differing time periods.

Section IX

ALTERNATIVES FOR GROUNDWATER QUALITY MANAGEMENT

GROUNDWATER PROTECTION AREAS

Existing groundwater quality management programs, such as the HMSO and the well sealing program, represent aggressive plans to protect aquifers for current and future use. However, given the prevalence of industrial chemicals used in the Santa Clara Valley and the relatively close proximity of major pumping zones to industrial regions, these programs alone may not insure groundwater protection. In the future, consideration should be given to locating water supply wells in regions removed from hazardous materials and to developing land use control measures to keep these regions isolated from hazardous material activities.

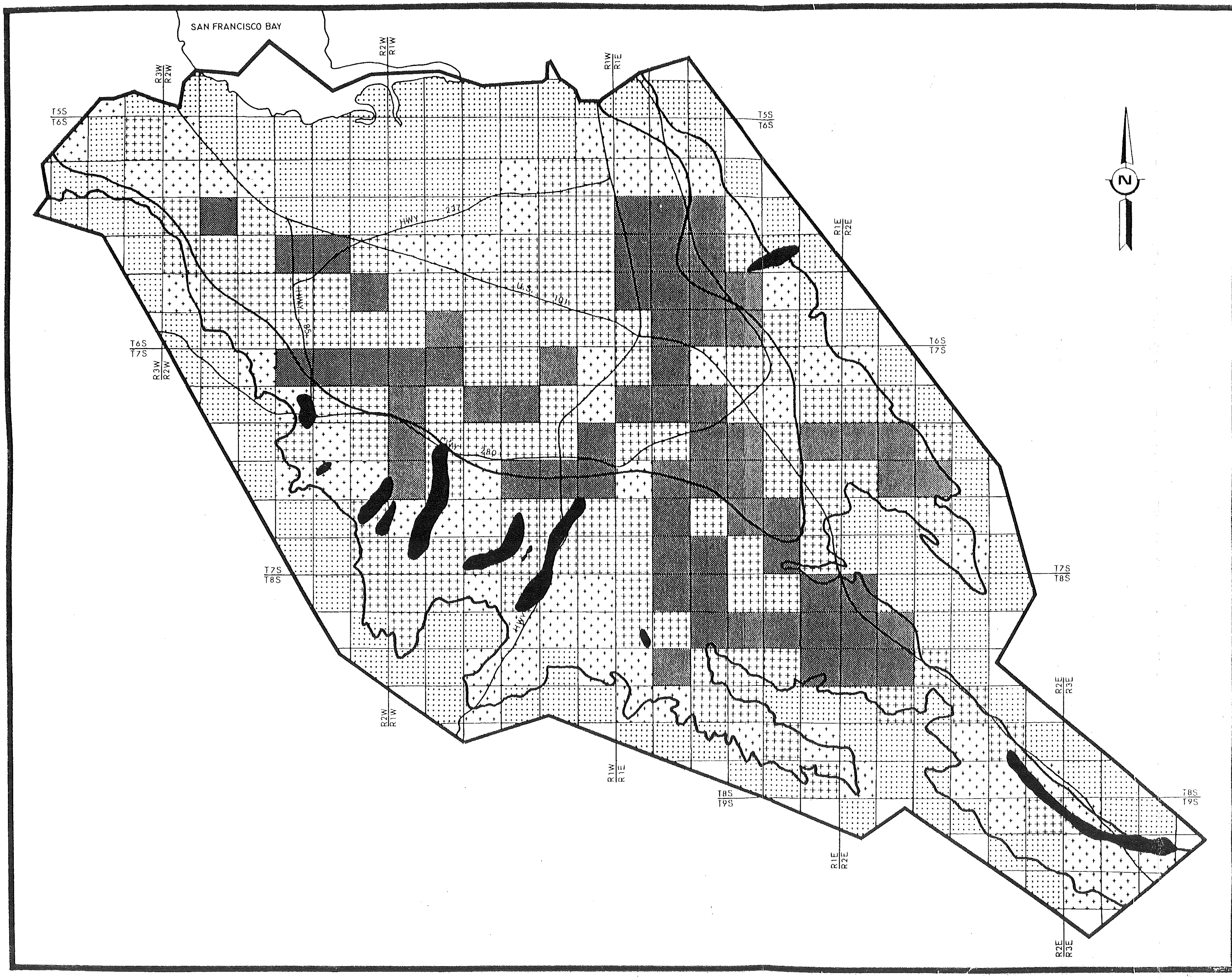
Comparison of the groundwater plume map (Figure VI-1) with the land use map (Figure III-3) for the Santa Clara and Coyote Subbasins indicates that contamination has occurred primarily in industrial and miscellaneous land use areas, while open space and residential land use areas have a much lower incidence of contamination. Therefore, open space and residential land uses not only are more compatable for groundwater extraction but also are favorable for future development of groundwater.

Delineation of Protection Areas. A recent report prepared by the National Committee on Groundwater Quality

Protection, established by the National Research Council, recommended that "land use controls be considered as an essential part of a groundwater protection program" (NRC, 1986). Land use controls have been used elsewhere in the country to isolate critical groundwater zones, such as aquifers sensitive to groundwater contamination or recharge zones, from sources of groundwater contamination, such as agricultural and industrial regions. In Santa Clara and Coyote Subbasins, critical areas can be delineated from a basin sensitivity map and a land use map. A basin sensitivity map ranks the relative susceptiblity of aquifers to contamination based on permeability, depth of aquifer, number and location of municipal and private wells, well production, the number of conduit wells, and geology. These six factors were combined and evaluated on a sectional (square mile) basis. This map, modified to include areas where stream and pond recharge occurs, is shown in Figure IX-1.

The most sensitive areas on Figure IX-1 are along the outer perimeter of the confined zone and in the forebay. Here groundwater is extracted in large quantities from numerous wells and where the most permeable soils are located. In addition, highly sensitive areas include recharge areas, where surface water readily percolates to the subsurface.

Figure IX-2 illustrates groundwater protection areas, based on the combination of the basin sensitivity map (Figure IX-1), the land use map (Figure VII-3), and the



L E G E N D

▒ LOW SENSITIVITY (LESS THAN 30 POINTS)

▒ MEDIUM-LOW SENSITIVITY (31-40 POINTS)

▒ MEDIUM-HIGH SENSITIVITY (41-50 POINTS)

▓ HIGH SENSITIVITY (GREATER THAN 50 POINTS)

LOW SENSITIVITY: AN AQUIFER OF MODERATELY LOW PERMEABILITY, OR AREA OF SALT WATER INTRUSION, OR NON-WATER BEARING BASIN FRINGE AREA, AND VERY SMALL NUMBER OF WELLS, AND SLIGHT IMPORTANCE AS A DRINKING WATER SOURCE.

MEDIUM-LOW SENSITIVITY: AN AQUIFER OF VARIABLE PERMEABILITY, AND SMALL NUMBER OF WELLS, AND IS OR CAN BE AN IMPORTANT DRINKING WATER SOURCE.

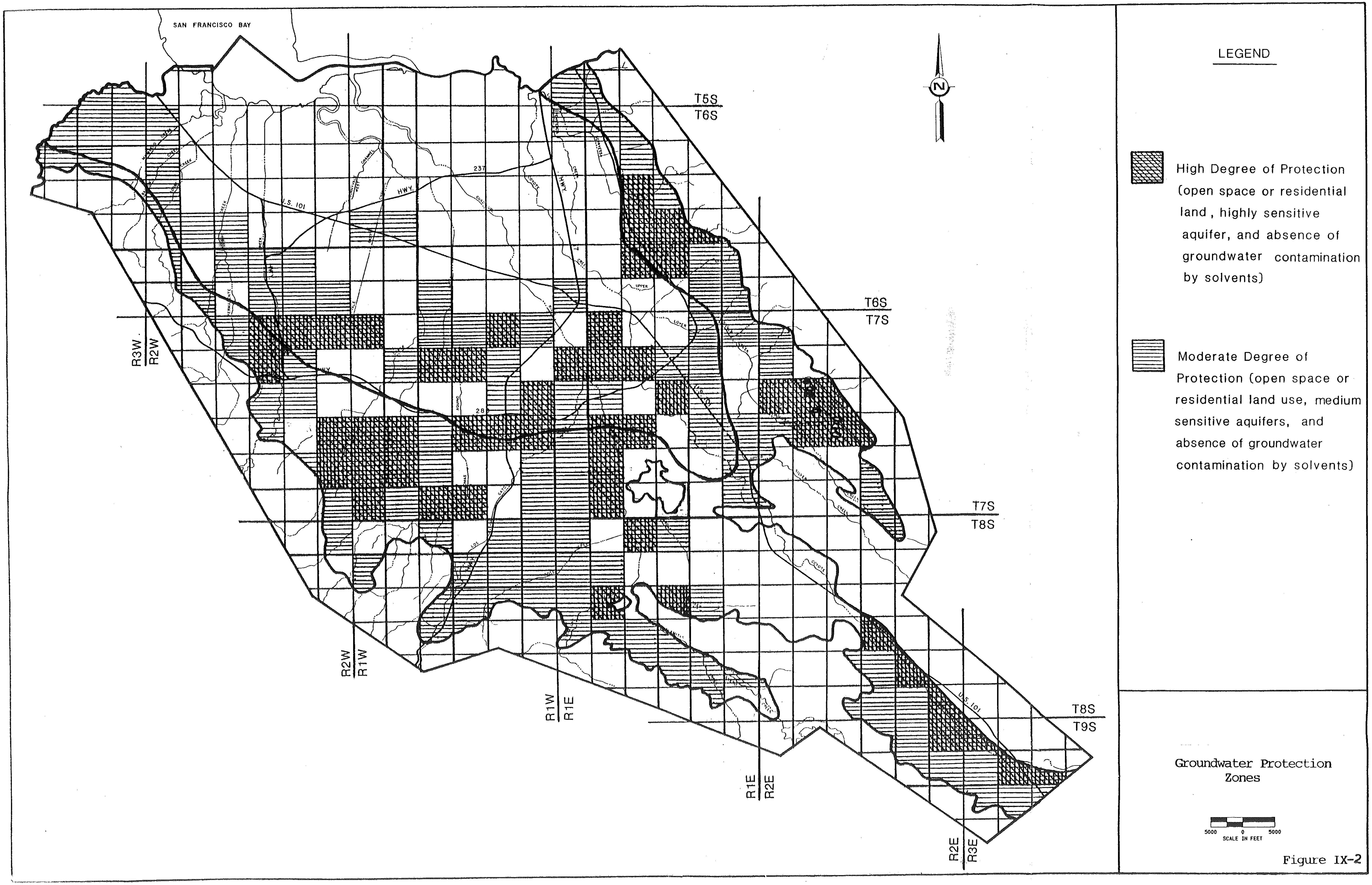
MEDIUM-HIGH SENSITIVITY: A MODERATELY PERMEABLE AQUIFER, AND MODERATE NUMBER OF WELLS, AND IS AN IMPORTANT DRINKING WATER SOURCE.

HIGH SENSITIVITY: A VERY PERMEABLE AQUIFER, AND EXPOSED AT THE SURFACE, AND LARGE NUMBER OF WELLS, IS AN IMPORTANT DRINKING WATER SOURCE

OR IS AN ARTIFICIAL RECHARGE [illegible]

Basin Sensitivity Map
(modified from
RWQCB, 1985)

Figure IX-1


SAN FRANCISCO BAY
N
T5S
T6S
T6S
T7S
T7S
T8S
T8S
T9S
R3W
R2W
R2W
R1W
R1W
R1E
R1E
R2E
R2E
R3E
237
HWY.
U.S. 101
28
UPPER
LOWER
COYOTE
LEGEND
▨ High Degree of Protection (open space or residential land, highly sensitive aquifer, and absence of groundwater contamination by solvents)
▤ Moderate Degree of Protection (open space or residential land use, medium sensitive aquifers, and absence of groundwater contamination by solvents)
5000
0
5000
SCALE IN FEET

Groundwater Protection Zones

Figure IX-2

groundwater contamination map (Figures VI-1). The high priority protection areas occur where highly sensitive basin areas and open space or residental land use areas coincide and contamination does not exist. High priority regions currently are used extensively for groundwater extraction. Ideally, the highest priority areas would be only those with open space; however, in the Santa Clara Subbasin little open space remains. Therefore, the high priority areas include open space and residential areas. Moderate priority areas are medium basin sensitive areas with residental or open space land use and where there is an absence of groundwater contamination. These aquifers are not fully utilized and represent potential areas for future expansion.

Together the high and moderate priority protection areas cover the perimeter of the confined region and a substantial portion of the forebay. High priority areas cluster just north and south of highway 280, east of highway 680 along Penitencia and Berryessa Creeks, east of Thompson Creek, and throughout Coyote Subbasin along Coyote Creek.

Groundwater protection areas signify regions favorable for development of future groundwater resources because of productive aquifers and isolation from industrial regions. Furthermore, these areas could be candidates for land use control measures to protect the groundwater basin for future use.

Implementation. Implementation of land use control protection measures has occurred in several communities in Massachusetts, New Jersey, Connecticut, and Florida (NRC, 1986). Specific mechanisms have included zoning by-laws, ordinances, or tax incentives. Zoning measures include zoning for increased lot sizes, density restrictions, bans on landfills and hazardous materials handling and storage, natural area preservation, site plan review, and rezoning industrial land to residential use in critical areas. In addition, zoning overlay districts are used when critical protection areas do not conform to existing town zoning districts. Establishment of zoning overlay districts has been reportedly easier than changing existing town zoning districts. Likewise, overlay zoning in the name of groundwater protection has warded off charges of exclusionary zoning and confiscation (NRC, 1986).

The HMSO adopted by nearly all juristictions in Santa Clara County, discussed in Section VII, is a good example of a non-zoning measure effective in areas already highly developed where rezoning would be difficult. Another non-zoning option would be to formulate a groundwater protection policy whereby industries would be given tax incentives to locate outside of sensitive portions of the basin.

GROUNDWATER MANAGEMENT ZONES

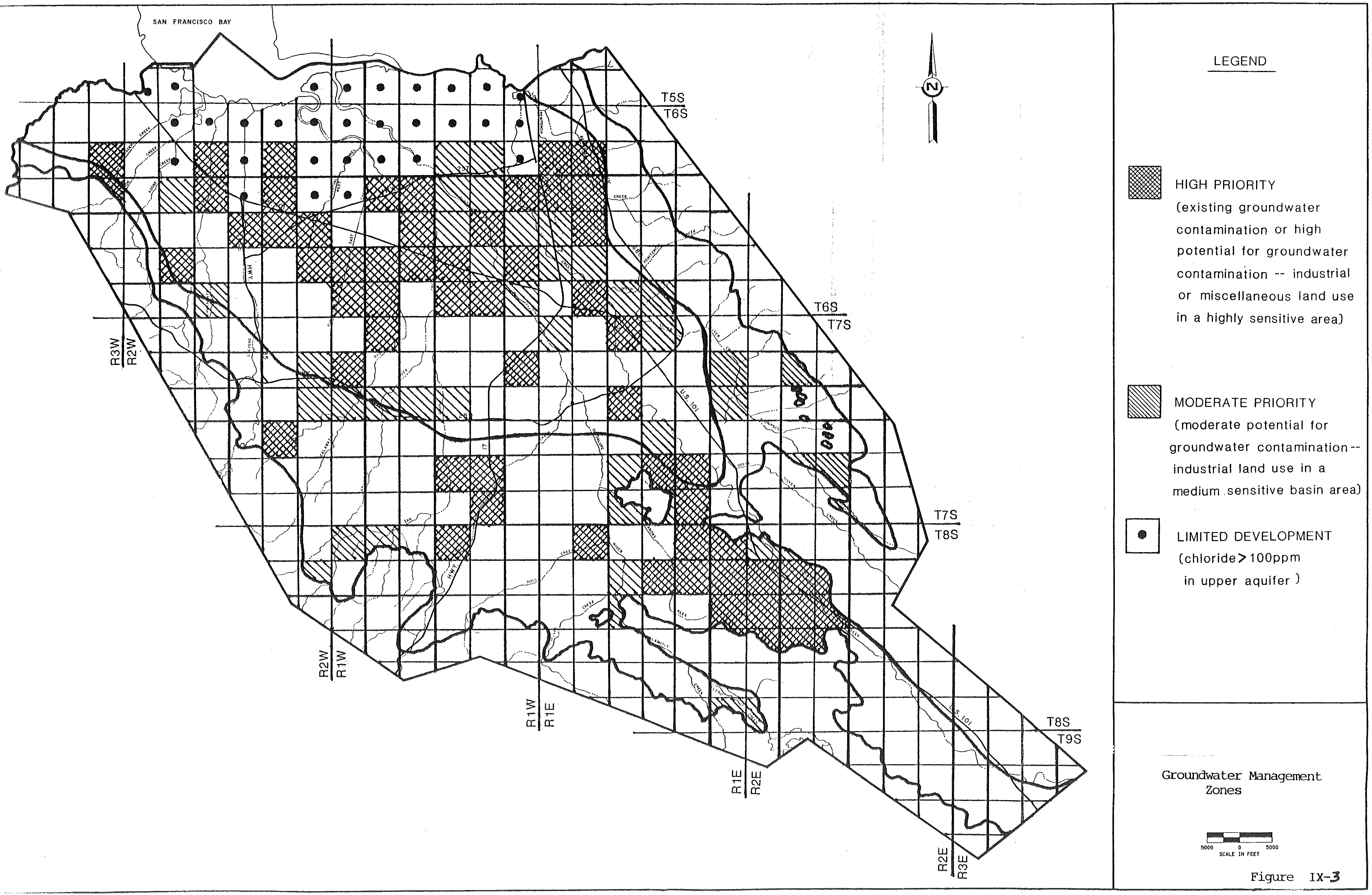
As indicated in Section VIII, the cost of abandoning the groundwater basin would be prohibitive. Clearly, areas surrounding existing groundwater contamination plumes will have to be carefully managed to insure that additional wells are not contaminated. New public water supply wells, irrigation wells, industrial wells, domestic wells, or extraction wells associated with groundwater clean-up efforts located near these plumes can influence the velocity and direction of contaminant transport. Because of the subdivision of the basin into zones utilized by different purveyors, there are geographic constraints as to where individual purveyors can locate new wells. In all likelihood, some purveyors may locate new wells in the vicinity of contamination plumes. Groundwater management zones could be developed to establish regions where groundwater pumpage and well siting should be regulated.

Location of Groundwater Management Zones. Groundwater management zones were defined as areas where existing groundwater contamination occurs or where the potential for contamination exists. Existing groundwater contamination was identified from Figures VII-1. Potential sites of groundwater contamination were evaluated from an overlay of the basin sensitivity map (Figure IX-1), and land use map (Figure III-3). As previously mentioned, industrial and miscellaneous land use areas have generated the greatest amount of groundwater contamination. Areas where the basin sensitivity is moderate to high and where industrial or miscellaneous land uses occur are prone to groundwater contamination.

Figure IX-3 shows groundwater management areas. High priority areas occur where known groundwater contamination exists or where a high potential for contamination prevails. Moderate priority basin management areas are situated where industrial or miscellaneous land use categories occur in medium basin sensitive areas, representing a moderate likelihood for future contamination. In addition, the portion of the basin with low suitability for future development, because of saline water in the shallow aquifer, is indicated.

The groundwater management areas are concentrated in the northern two-thirds of the confined area, in the unconfined area north of Coyote Narrows, and in scattered locations throughout the forebay.

Implementation. Implementation of a groundwater management plan for controlling contamination could include regulation of well siting and pumpage. Public water supply wells in the Santa Clara Subbasin are already subject to this type of regulation. Under the State Environmental Quality Act any new public water supply well operator must document any potential source of pollution within a two mile radius of the well. If a potential source exists, then a detailed report determining the effect of pumpage on contamination plume must be submitted to the DOHS.


SAN FRANCISCO BAY
N
T5S
T6S
T6S
T7S
T7S
T8S
T8S
T9S
R3W
R2W
R2W
R1W
R1W
R1E
R1E
R2E
R2E
R3E
HWY. 17
HWY.
U.S. 101
U.S. 101
237
LEGEND
▩ HIGH PRIORITY (existing groundwater contamination or high potential for groundwater contamination -- industrial or miscellaneous land use in a highly sensitive area)
▧ MODERATE PRIORITY (moderate potential for groundwater contamination -- industrial land use in a medium sensitive basin area)
● LIMITED DEVELOPMENT (chloride > 100ppm in upper aquifer)
5000
0
5000
SCALE IN FEET

Groundwater Management Zones

Figure IX-3

This type of requirement could be expanded to cover any new well, such as an extraction well at a groundwater contamination site or an irrigation well. Special emphasis would be placed on wells located within the management zones. New wells could be identified during the permitting process. The SCVWD is involved with the permitting of new wells and, therefore, could require the permittee to establish the pumpage impacts of any new, non-public water supply well.

GROUNDWATER BASIN MODELS

Predictive and Resource Management Models. Models are tools that can assist in basin management by nature of their predictive and management decision capability. Fundamentally, a prediction model provides an efficient way to synthesize all of the hydrologic characteristics of a groundwater basin to predict how the basin will respond. Resource management models are hybrids, combining features of the predictive model with allowance for management concerns regarding optimal use of the basin.

Models used for aquifer simulation are essentially computer codes that solve mathematical equations governing groundwater flow. Input information includes initial water levels, aquifer characteristics (transmissivity and storativity), well locations and pumpage rates, recharge conditions, and boundary conditions. The resultant output includes computed change in groundwater levels throughout the basin over the time period the model is run.

In addition to models that simulate physical basin parameters, resource management models have been used to evaluate costs of developing groundwater and to evaluate fiscal policies to stimulate efficient basin-wide use of groundwater (AGU, 1980). Management models consist of several components that integrate decision-making options into the model and predict the outcome of this decision under a given set of constraints. Constraints can include political, economic, and physical limitations. The utility of management models is in establishing the best management plan which meet pre-set objectives, such as cost savings or optimal groundwater yield.

Development of a Hydrologic Model. Model development ideally encompasses five phases (not necessarily in sequential order):

1. Data collection, analysis, and compilation.
2. Calibration of the model to actual field observations.
3. Verification of the calibrated model.
4. Prediction of aquifer responses to conditions of interest.
5. Sensitivity analysis.

During the first stage, historical data are compiled. Based on the availability of historical records, the base period is established. Ideally the base period, or the period during which the model is calibrated, should include a range of hydrologic conditions, such as drought and wet years. In practice, it may be difficult to obtain data spanning such conditions. In general, the longer the base period the better the model.

The second stage of model development is termed calibration. Calibration is the process of comparing observed conditions (commonly, groundwater levels) with conditions computed by the model. Model input data are adjusted within reasonable limits until a suitable match between computed and observed conditions is achieved. During calibration, additional data may be gathered if necessary. During the third stage, the calibrated model is verified by running it with a different set of historical conditions. If the results do not match the historical water levels, the model must be recalibrated.

In the fourth stage the model is run with input data reflecting future conditions. For example, the effects of increased pumpage or artificial recharge could be simulated. In the fifth stage the sensitivity of the model is evaluated. This entails modifying the input parameters, one at a time, and observing the effect on the output. This step facilitates determination of how sensitive the model output is to error in the input data and identification of particular parameters which significantly affect the prediction of basin behavior.

Given the relative complexity of the Santa Clara Basin in terms of geology, hydrology, and sources of groundwater recharge and extraction, a predictive model can assist in testing current hypotheses about how the basin functions. For example, various amounts of recharge from basin boundaries, the occurrence of groundwater leakage through the confined zone, and the impact of a long-term drought on water levels are a few scenerios that could be rigorously tested. A basin model can also provide background information for more specific groundwater contamination studies. Regional transmissivities, groundwater gradients, and boundary conditions are examples of such information.

Development of a groundwater basin model provides an impetus to collect, manage, and assimilate information more coherently for planning purposes. A positive side affect of this iterative process can be increased communication among field personnel, technical staff, planners, and managers.

Groundwater models which have been developed for Santa Clara Basin are discussed in Section V.

CLEANUP ALTERNATIVES

Sequence of Remedial Actions. Whenever and wherever contaminants are found in soil and groundwater, a series of decisions involving investigational, control, treatment, and monitoring procedures is initiated. Wrong decisions based on incomplete data or analysis can be costly and ineffective; therefore, careful attention is required by the various concerned entities. The sequence of steps normally includes the following (Magner, 1985):

(1) Characterize contamination--to assess contaminants and amounts, sources, extent of the problem, and health risks.

(2) Define hydrogeology--to describe geologic stratigraphy, aquifers, and dynamics of contaminant plumes.

(3) Review remediation options and select course of action--to determine containment, removal, treatment, or some combination thereof.

(4) Formulate cleanup objectives--to select the water quality objective based on health, technical, environmental, and economic factors.

(5) Identify feasible technologies--to consider physical, chemical, and biological approaches.

(6) Conduct feasibility studies--to evaluate alternate treatments.

(7) Select treatment methods--to conduct pilot studies and then design full scale facility.

(8) Initiate monitoring program--to determine the effectiveness of the remediation program.

Groundwater Treatment Technologies. Treatment methods for contaminated groundwater can be divided into three basic categories: physical, chemical, and biological. These methods are briefly described in the following paragraphs with emphasis on floating hydrocarbons and volatile organic compounds (VOCs), both of which are predominant contaminants in Santa Clara Valley.

Air Stripping. Air stripping is a process whereby a compound dissolved in water becomes dissolved in air. This is an effective treatment method for removing VOCs from groundwater because these chemicals dissolved in water naturally diffuse into available air. The transfer of a contaminant from the liquid phase to the gaseous phase is accomplished by injecting air into the water using various aeration designs and techniques.

Adsorption. Adsorption is a physical process whereby molecules of a gas, liquid, or a dissolved substances adhere to a surface. Adsorbent surfaces include naturally occurring adsorbents such as activated carbon and synthetic resins. Activated carbon is the most widely used adsorbent in the water industry because it is a broad spectrum adsorbent and is also very efficient in removing total organic carbon.

Reverse Osmosis. Reverse osmosis, a third physical process, is an osmotic filtration process that separates dissolved inorganic and organic material from water. This filtration is done with a membrane more permeable to water than to the solute and by applying pressure, up to 1500 psi, that exceeds the osmotic pressure of the solution. The pressure causes a water flow through the membrane, leaving the contaminant behind. Although reverse osmosis is highly effective in removing inorganics, its efficacy with organic compounds is somewhat more variable.

Skimming. Skimming is the physical removal of floating contaminants (oil, grease, gasoline, and other light hydrocarbons) from a multi-layer solution. The process of removing floating hydrocarbons (free product) can take place directly in a well or at an above ground collection point. Various systems are available to recover floating hydrocarbons; these include infiltration trenches, skimmer systems, oil/water surface separation, and one- and two-pump recovery systems.

Chemical Oxidation. In treating hazardous materials, oxidation is used primarily to convert compounds to less toxic forms or to carbon dioxide. Ozone is a powerful oxidizing agent and is capable of oxidizing compounds such as chlorinated hydrocarbons, chlorinated aromatics, and pesticides (Guswa, 1983). The oxidation of these organic compounds is improved by combining ultraviolet light with ozonation.

Surface Biological Treatment. In surface biological treatment of contaminated groundwater, organic compounds are degraded by microorganisms in aerobic or anaerobic processes. Biodegradation in aerobic oxidative processes degrade organic compounds to carbon dioxide and water, while anaerobic processes decompose organic matter to carbon dioxide and methane gas.

In Situ Biological Treatment. In situ biological treatment involves the same biodegradation process as surface biological treatment; however, the difference is that the in situ treatment occurs in the subsurface. Three approaches are available:

(1) Seed the subsurface environment with microbes adapted to degrade the specific pollutants.

(2) Enhance the indigenous microbial population with nutrients such as oxygen sources, nitrogen, phosphorus, and trace metals.

(3) Modify the contaminant by dispersal or emulsification to make it more amenable to biodegradation.

The pumping strategy in a typical bioreclamation program controls the movement of nutrients and water through an injection, withdrawal, and recharge system. Candidate compounds for subsurface biodegradation include simple hydrocarbons, selected aromatics, compounds with one chlorine atom, simple amines, alcohols, esters, ketones, and ethers. Because this is a rapidly emerging technology, predictions of the effectiveness of the treatment are still tentative.

Soil Treatment Technologies. Treatment of contaminated soils and unsaturated sediments often is required to prevent migration of contaminants to the underlying groundwater. Major methods are incineration, disposal, and vapor extraction.

Incineration. Incineration can be employed for removal of contaminants from unsaturated soil. Typically, this would involve excavation of the soil, passage through an on-site incineration plant, and replacement in the ground.

Disposal. For shallow soil contamination, excavation and transport to a Class I disposal site can be done. The hole created is filled with clean soil. The idea of moving contamination from one site to another is environmentally unsound, hence State regulatory agencies discourage the practice.

Vapor Extraction. A relatively new approach for removing contaminants from unsaturated soil makes use of numerous small tubes inserted into the ground. A suction is applied to the tubes which removes air containing VOCs from the soil.

Groundwater Control and Containment. Groundwater contamination can be controlled by containing rather than treating the contamination source or plume. Such an approach is designed to prevent hazardous compounds from entering groundwater or to restrict the movements of contaminated groundwater. In some cases both treatment and containment may be appropriate. Categories of control and containment technologies include impermeable barriers, groundwater pumping, leachate collection, removal, and surface water control (Guswa, 1983). Each is briefly described in the following paragraphs.

Impermeable Barriers. Impermeable barriers are physical barriers designed to restrict groundwater flow. The most common types are slurry walls, grout curtains, and sheet piles. Slurry walls are constructed by digging a trench using a bentonite-water slurry to maintain the trench during excavation. The trench is then backfilled with a soil-bentonite or cement-bentonite mixture which forms a low permeability barrier. Grout curtains involve injecting materials into the ground under pressure to seal voids in porous or fractured rock. Sheet piling cutoff walls are constructed by driving web sections of steel sheet piling permanently into the ground. At the Fairchild contamination site in South San Jose, a rectangular slurry wall with depths exceeding 100 feet was constructed to hydraulically isolate a shallow aquifer contamination source.

Groundwater Pumping. Groundwater pumping utilizes one or more pumps to extract groundwater through a series of wells forming a cone of depression in the water table or piezometric surface. Shallow well points or deep well systems can be employed, depending on the depth of the aquifer. Groundwater pumping can be used to lower the water table, contain a plume, or remove contaminated groundwater. The method has been used at several locations in Santa Clara Valley to bring contaminated water to the surface for treatment and disposal.

Leachate Collection. Leachate collection methods include use of subsurface drains or drainage ditches. Subsurface drains are constructed by placing tile or perforated pipe in a trench, surrounding it with a gravel envelope, and backfilling with topsoil or clay. Shallow groundwater draining into the trench is removed by a well or sump pump. Drainage ditches are open trenches designed to collect surface water runoff, collect flow from subsurface drains, or intercept lateral seepage of water.

Removal. Removal of the source of contamination may involve excavation of loose, drummed, or tanked waste and contaminated soil, or pumping of impounded liquids. Removal is most appropriate when the source is small, such as an underground storage tank or an isolated spill site.

Surface Water Control. A variety of technologies are available to control surface water flow at or near a contamination site. Included are dikes, terraces, channels, grading, surface seals, and vegetation. These facilities serve to control surface water entering a site, to minimize infiltration, to reduce erosion, and to collect and transfer water. Management of surface water is important because the entire water balance can affect major groundwater contamination sites.

Groundwater Treatment Locations. Almost all groundwater treatment for contamination in Santa Clara Valley occurs at the source of contamination or nearby in the associated plume area. The treated water may be recharged into the ground for subsequent beneficial use, or it may be discharged into surface channels which carry it out of the basin. In either case the purpose is to maintain the highest quality groundwater in the basin at all times and places. However, treatment and disposal represents a loss of water resources, while treatment and recharge is both costly and often infeasible in an urban area.

Certainly with numerous contamination sites in Santa Clara Valley, it may prove impractical to design and operate a comparable number of treatment facilities.

One alternative is permit the contamination to remain in the groundwater and to mitigate only the source. By so doing the contamination will gradually decrease in concentration both with time and distance migrated due to natural attenuating mechanisms such as dilution, adsorption, and degradation. At some downstream point where groundwater containing residual contaminants is extracted for beneficial use (the point of use), treatment is then applied to meet appropriate water quality standards. This procedure would conserve groundwater, avoid the problems and costs of recharging treated water, and require lower levels of treatment and fewer treatment plants.

For a municipal or private water company supplying retail municipal and industrial water, this would require its operating a water treatment plant to meet applicable water standards. The cost of such a plant could be assessed to the industries initially responsible for the contamination, presumably in proportion to the contamination contributed. Thus, one centralized treatment plant should be more economical than a large number of plants each associated with an individual contamination site.

An additional consideration are private wells, which are susceptible to the same pollutants that contaminate municipal wells. Here the options open to the owner of a contaminated private well include:

(1) Purchase bottled water or boil water for drinking.

(2) Tie into an existing municipal system.

(3) Install a point-of-use treatment system.

The first choice is temporary at best and carries the risk of inhaling VOC-laden vapors while bathing. The second may be costly depending on the location of the property. For the third option carbon adsorption or air stripping units for home use are being developed; however, the reliability of the effluent water quality under long term operating and maintenance conditions in a private home has yet to be demonstrated.

A further complication to the point-of-use treatment approach is the Water Code of the State of California, which states that the waters of the State shall be protected and not wasted. The nondegradation aspect is also under study on a national level by the U.S. Environmental Protection Agency. In the future it may occur that aquifers have differing water quality requirements dependent upon a variety of local conditions.

NO-ACTION ALTERNATIVES

Two basic no-action alternatives could be considered. The first involves cessation of groundwater clean-up programs but continued use of the groundwater basin, while the second alternative entails abandonment of portions or all of the groundwater basin.

Groundwater Use Without Clean-Up. This is not a viable option, because it entails violation of laws and regulations regarding the quality of the waters of the State and public health. Furthermore, citizens would not tolerate a policy that permits a general threat to public health and transfers the burden of water quality protection from private manufacturing companies and public agencies to the private citizen and consumer. Such a transfer of responsibility would be inequitable, as groundwater consumers would be compelled either to bear the costs of treating their water or replacing it with bottled water, or to use contaminated water.

Abandonment of Groundwater. This alternative entails cessation of clean-up activities and abandonment of contaminated portions of the groundwater basin. Like the preceding alternative, this is not a viable option at present because it violates the non-degradation standard for the water resources of the State. Furthermore, as pointed out in Section VIII, such an alternative represents forfeiture of a valuable resource and loss of the existing investment in developing that resource. The benefits yielded by the basin would have to be replaced at considerable monetary and environmental cost.

Section X

CONCLUSIONS

It is to the District's credit that the Santa Clara Valley groundwater basin has never been adjudicated for water rights--a costly and inefficient process--in spite of the large number of pumpers and the competition for water. Instead, policies of benevolent guidance and maintenance of close working relationships with water purveyors have enabled the District to meet an ever-growing water demand without major legal challenges. Continuance of this philosophy into the future should enable the District to ensure that the residents of Santa Clara Valley have a water supply adequate in quantity and quality.

As a groundwater basin is developed over time, its importance and economic value increases. This is certainly true for the Santa Clara Valley basin. But at the same time the effect of problems such as overdraft, emergencies, and contamination increase. The interactions of ever-larger volumes of water entering and leaving the basin together with an expanding urban environment tend to adversely affect both water quantity and quality. Thus, a need exists to recognize the basin as an entity and to manage it as a whole.

Summary of Conclusions from Individual Sections

Section II

1. The geology of the Santa Clara Groundwater Basin is characterized by discontinuous lenses of clay, silt, sand, and gravel. Regional cross-sections have been based on driller's logs; they provide a highly generalized picture of the geology.

2. The natural groundwater yields are 58,200, 4,400, and 45,200 acre-feet/year in the Santa Clara, Coyote, and Llagas Subbasins, respectively.

3. Recharge occurs in the forebay of Santa Clara and Llagas Subbasins and throughout Coyote Basin.

4. Hydraulic separation between the shallow (less than 150 feet) and deep (greater than 150 feet) aquifers has been firmly established in some portions of the confined area in the Santa Clara Subbasin; however, the irregular distribution of sand lenses and the variation in hydraulic conditions due to pumpage in the deep aquifer implies that this separation may not be consistent throughout the confined area.

5. Most high volume wells in the Santa Clara Subbasin tap the lower aquifer or the forebay, while private wells tap the upper aquifer. Many wells are screened at multiple levels.

Section III

1. Population and total water demand have increased significantly in Santa Clara County since the 1950s.

2. Water demands in Santa Clara County are projected to increase to 468,200, 498,500 and 549,500 acre-feet/year in 1990, 2000, and 2020, respectively.

Section IV

1. Sources of water supply for Santa Clara County include imported water, local surface water, and local groundwater.

2. Groundwater from natural and artificial recharge provides 58 percent of all water produced in Santa Clara Valley.

3. A shortfall in water supply could occur in the Santa Clara and Llagas Subbasins in the year 2000. However, temporary depletion of groundwater storage can fulfill water demands.

4. Water supplies are sufficient to meet projected demands in the Coyote Subbasin in the year 2000, and in all three subbasins in the year 2020.

5. In the event of a moderate drought, water conservation can compensate for much of the shortfall in supply. However, groundwater storage will be depleted to some degree, possibly resulting in localized problems such as water table decline, recurrence of subsidence, and seawater intrusion.

6. The shortfall in water supply during a severe drought could be compensated by strict conservation measures and groundwater storage depletion. Local problems due to increased pumpage could be severe. In addition, facilities to pump and transmit groundwater could be overtaxed.

Section V

1. Groundwater management currently focuses on sustaining the yield of the basin through artificial recharge. This program mitigates problems associated with seawater intrusion and land subsidence.

2. Shallow groundwater occurs in portions of all three subbasins as a result of naturally occurring high water tables and also occurs occasionally in Llagas Subbasin due to rise of piezometric levels in the confined area.

3. The total volume of artificial recharge is estimated at 135,790 acre-feet in 1986.

4. Various groundwater models have been developed for Santa Clara Valley; however, none have yet provided a definitive basis for future groundwater management decisions.

Section VI

1. Both surface water and groundwater in the Santa Clara Valley are calcium-magnesium bicarbonate type waters.

2. Surface water quality is monitored in an ongoing SCVWD/USGS program. Early data (1979 - 1981) indicate elevated mineral concentrations attributable to geological, agricultural, and urban sources. Additionally, 15 biocides were detected at low levels in surface water during 1979 - 1981.

3. Elevated THM is a problem at SCVWD water treatment plants; a pilot treatment plant at Rinconada will be constructed to evaluate the effectiveness of ozonation as an alternative treatment technology.

4. Groundwater has been contaminated by industrial solvents, gasoline, and agricultural chemicals. Industrial solvents have been the focus of intensive investigations, and over 26 plumes have been delineated. Over 480 sites involve gasoline contamination. Agricultural fertilizers have been responsible in part for elevated nitrate concentrations in Llagas Subbasin.

5. Almost all solvent contamination in the Santa Clara Subbasin has been restricted to the upper aquifer in the confined area. In the forebay there have been a few large contamination plumes.

6. Nearly 2.6% of the Santa Clara Subbasin is underlain by contaminated groundwater. The volume of contaminated groundwater is approximately 45,000 acre-feet, or 3.8% of the total storage in the shallow aquifer in the Santa Clara Subbasin.

7. Concentrations of pollutants measured in public water supply wells have generally been below DOHS action levels. At least 94 wells (38 public and 56 private) have had detectable levels of VOC's. This represents 14.7% of public water supply wells and 4.6% of private wells in the Santa Clara Subbasin. As of 1986, ten public water supply wells were closed, while an additional eight were on standby status.

8. In terms of volume, the amount of groundwater that is contaminated is relatively insignificant; however, increased adverse impacts on water supply wells are possible unless careful monitoring and management of the groundwater resource are undertaken.

9. In the high density plume area, deep aquifers have a degree of natural protection; however, several sections in this region have a relatively high number of abandoned wells, which could act as contaminant corridors.

Section VII

1. Current groundwater protection programs are designed to diminish point source releases of contaminants (HMSO and Fuel Leak investigations), and interaquifer transport of contaminants (well sealing program). Programs have not reached full implementation, but will

increase the degree of groundwater protection and lessen the costs of groundwater cleanup borne by industry and public agencies in the future.

2. To date 144 wells have been sealed as part of the SCVWD program. This number is 33% of the total wells targeted for sealing. A total of one million dollars has been allocated for this program.

3. The SFRWQCB and the DOHS oversee groundwater cleanup in the Santa Clara Subbasin. As of September 1986 a total of 51 sites required soil removal, while 61 sites required groundwater extraction/containment. Compliance has been voluntary, but over half of the site are running behind schedule.

4. To date there has been no reported interference between groundwater extraction for contaminant remediation and municipal water supply wells. The volume at all contaminated sites amounts to 28% of the natural groundwater yield of Santa Clara Subbasin and 9% of 1985 public and private pumpage.

Section VIII

1. Benefits of the current system of groundwater use include development of the natural yield, approximately 107,800 acre-feet/year.

2. The area most significant to maintenance of the natural yield is the basin forebay, especially areas along streams and areas occupied by irrigated agriculture, open space, and residential land uses.

3. Groundwater use also takes advantage of the basin's huge storage capacity, particularly in times of drought or other shortfalls in water supply. It also provides a natural water treatment and distribution system

4. The artificial recharge program, amounting to more than 100,000 acre-feet/year, takes advantage of the storage, treatment, and distribution benefits, particularly in portions of the groundwater basin situated between artificial recharge facilities and major production wells.

5. Numerous water sources exist as possible alternatives to the groundwater yield. However, it is unlikely that any one alternative, except water transfer from agricultural areas, could replace the total groundwater yield.

6. As an alternative to groundwater development, surface water could provided through surface reservoir storage, water treatment plants, and surface canals and pipelines. Comparison of costs, however, indicates that continuing the current system of groundwater use is more cost effective.

Section IX

1. Groundwater protection areas are those favorable for development of future groundwater resources, because of their productive aquifers and isolation from industrial regions. Such areas provide a buffer zone between sensitive portions of the basin and industrial areas. Land use control measures such as zoning by-laws, ordinances, or tax incentives can insure maintenance of protection areas.

2. Groundwater management areas occur where known groundwater contamination is found or where a high potential for contamination prevails. Implementation of a management plan in these areas could include regulation of well siting and pumpage.

3. Groundwater models can assist in management of the basin. A predictive model would enable testing of hypotheses regarding future basin operations and could provide background information for more specific groundwater contamination investigations.

4. A variety of treatment methods for removal of contaminants from groundwater have been developed in recent years. Chief among these are air stripping, adsorption by activated carbon, and reverse osmosis.

5. Groundwater contamination can be controlled by impermeable subsurface barriers, pumping, leachate collection, and surface water control; all of these methods are widely employed in urban areas.

6. Contaminated groundwater can be treated at the source of contamination or at the point of use. The latter alternative, however, poses environmental and regulatory problems which generally make it infeasible.

Section XI

RECOMMENDATIONS

In recent years much attention in Santa Clara Valley has been focused on site-specific contamination, and necessarily so, but in the future a broader approach to groundwater concerns also will be required. Many of the following recommendations suggest a basin-wide approach to groundwater management. Matters such as data base management, basin modeling, protection and management zones, and emergency planning require treatment on a unified basis. Much of the District's past successful work has embodied basin-wide management; these recommendations simply amplify and extend that concept.

Geologic Analyses

There is a need for more detailed geologic information to evaluate the continuity of the clay layer above the confined zone and the degree of protection it provides to the underlying deep aquifer. The potential for contaminant migration through sand lenses between the shallow aquifer and the deep aquifer should be investigated. Geologic cross-sections should be prepared across zones of contamination, industrial land use areas, and major zones of pumpage.

Cleanup of Soils and Groundwater

The SFRWQCB, the CCRWQCB, the DOHS, and the EPA regulate groundwater cleanup in Santa Clara Valley. In light of the significant benefits provided by the groundwater basin, and the substantial monetary and environmental costs involved in replacing those benefits, it is essential that groundwater cleanup programs be continued. There is a need to establish appropriate cleanup levels throughout the basin and to determine how best to apply the non-degradation standard of the State of California in a consistent manner.

Fuel Tank Program

There are at least 489 known sites of gasoline contamination in Santa Clara Valley, at least 120 of which are known to involve groundwater contamination. Staff shortages at the SFRWQCB have slowed fuel tank investigations. Recent staff additions of staff, provided by the SCVWD, will help to expedite these investigations. It is recommended that the SCVWD, in cooperation with the San Francisco RWQCB and Central Coast RWQCB, compile information from individual sites and prepare regional site and plume maps describing the dissolved constituents present in groundwater.

Underground Tank Storage

A Hazardous Materials Storage Ordinance is currently in place in all jurisdictions in Santa Clara Valley. These ordinances require secondary containment and monitoring systems. It is recommended that the District encourage cities to reach full implementation of their ordinances by their respective target dates.

Conduit Well Sealing

The District initiated a well sealing program in recognition of the threat posed to groundwater quality from abandoned wells. These wells can serve as conduits between shallow and deep aquifers. Target zones for well sealing are located in the vicinity of existing contaminant plumes. Given the relatively high concentration of conduit wells near contaminant plumes, it is recommended that the District accelerate the program to complete sealing of all targeted wells. In addition, as new solvent sites and high density fuel leak areas are identified, the program should be modified to include these areas.

Well Design Standards

To maintain high quality groundwater throughout Santa Clara Valley, attention must be given to proper design and construction of water supply wells. This can be accomplished where knowledge of geology and contamination are sufficient. The District is the only entity capable of ensuring that basin groundwater quality is maintained in the future. Therefore, it is recommended that the District work in cooperation with DOHS to assure that all future wells are properly sited, screened, and sealed.

Groundwater Quality Monitoring

The quality of groundwater existing within Santa Clara Valley is a mixture of water from different sources. Although some 60 wells are currently being monitored by the

District, there is need for an expanded coverage over the entire basin both for management purposes and for public information. It is recommended that the District work to establish an enhanced basin-wide groundwater quality monitoring program. This should embrace mineral and organic analyses and be done in cooperation with the water purveyors.

Water Level Monitoring

The District's current groundwater level monitoring program encompasses 250 wells. It is recommended that the District develop a gradually expanded program replacing water supply wells with permanent monitor wells. It is important that the program include wells screened above the confined zone (in close proximity to existing deeper wells) in Santa Clara and Llagas Subbasins so that vertical gradients can be evaluated.

Artificial Recharge

The several artificial recharge facilities operated by the District have proven to be efficient and effective in making additional groundwater available for subsequent use. These facilities typically are operated independently, and the amount of water recharged in each is controlled by the locally available storage and surface runoff. In the future larger amounts of imported water will be available for recharge in Santa Clara Valley, and the effect of each recharge facility on groundwater levels will become more important. Therefore, it is recommended that the District evaluate the maximum capability of each recharge facility with a view toward future coordinated operation of the facilities to achieve optimal basin management.

Protection Zones

Protection zones as defined in Section IX represent areas within Santa Clara Valley where important groundwater resources occur and where there is currently little opportunity for contamination. In other words these areas contain productive aquifers which are removed from potentially harmful industrial sites. To insure the future availability of potable groundwater, these areas need to be protected. Therefore, it is recommended that the District study the concept of protection zones and encourage cities and the county to implement land use controls in broad areas where urbanization could adversely impact groundwater resources.

Management Zones

Management zones as defined in Section IX are areas within Santa Clara Valley where major groundwater resources occur together with industrial areas and known groundwater contamination. Such areas are the most vulnerable to destruction of groundwater resources. To avoid loss of groundwater resources in these critical areas, attention needs to be given to well location and design, pumpage rates, and also control of existing contamination. Therefore, it is recommended that the District recognize the idea of management zones as a means of focusing attention on critical groundwater resources.

Basin Modeling

Given the relative complexity of Santa Clara Valley in terms of geology, hydrology, and sources of groundwater recharge and extraction, a predictive groundwater basin model should be an integral part of groundwater planning and management. The basin model should be used to test hypotheses about how the basin can be operated and to identify critical data gaps. The SCVWD's current efforts toward developing a model should be continued with a long term commitment to maintaining and refining the model.

Data Base Management

Considerable amounts of data are generated for Santa Clara Valley relating to groundwater quality and quantity. These data provide a foundation for evaluation of regional trends in groundwater and surface water quality and quantity. However, because these data are housed within a number of different agencies, it is difficult to evaluate such trends. If the data were maintained and organized in a structured, centralized fashion they would be of greater utility. It is recommended, therefore, that the District evaluate the feasibility of a centralized data base management program. Consideration should be given to anticipated applications of the data and to the accuracy and precision of the data.

Library of Groundwater Information

A wealth of information exists relating to groundwater in Santa Clara Valley by sources such as the SCVWD, Gavilan Water District, consultants, industry, purveyors, regulators, and others. Identifying and collecting available information from the multitude of sources in a timely manner can be an overwhelming task. It is therefore recommended that the District consider establishing a library of this information that would be available to interested parties and the general public.

Emergency Planning

At present the numerous water purveyors in Santa Clara Valley work closely with the District in achieving a balance between water supply and water demand. In the future, however, lies the potential for an emergency situation wherein a substantial loss of available water might occur. Three situations, for example, can be considered: loss of a portion of the groundwater storage due to contamination, loss of imported water due to an earthquake, and severe cutbacks on imported water due to a state-wide drought. Should any such event occur, it will be important that plans exist for appropriate responses by the District and purveyors. Therefore, it is recommended that the District, in conjunction with the water purveyors, prepare contingency plans for operation of water sources and water distribution systems under emergency conditions.

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GLOSSARY

Aquitard - A geologic formation which impedes groundwater movement and does not yield water freely to wells, but that may transmit appreciable water to or from adjacent aquifers and, where sufficiently thick, may constitute an important groundwater storage zone.

Artificial recharge - The augmentation of the natural movement of surface water into underground formations.

Calibration - The process of adjusting or fine-tuning a computer model or hydrologic budget.

Chloramination - The application of chlorine and ammonia to water for the purpose of disinfection.

Chlorination - The application of chlorine to water or wastewater, generally for the purpose of disinfection.

Class III sanitary landfill - An earth-covered disposal site appropriate for nonhazardous solid waste.

Coagulation - The aggregation of fine suspended matter in water or wastewater brought about by the addition of chemicals or by biological processes.

Coliform - A type of bacteria predominantly inhabiting the intestines of man or animal.

Conduit well - A well, often improperly sealed or abandoned, which allows the migration of groundwater from one aquifer to another.

Cone of depression - The conical zone around a well in which groundwater levels are lowered as a result of pumpage of the well.

Conjunctive use - The planned use of underground storage in coordination with surface water supplies to increase the yield of the total water resource.

Contamination - The degradation of natural groundwater quality to such an extent that it can constitute a hazard to human health if Federal drinking water standards or state action levels are exceeded.

Distillation - A process of evaporation and recondensation which can be used to separate water from dissolved constituents.

Filtration - The process of passing a liquid (water or wastewater) through a filtering medium in order to remove suspended matter.

Finite difference model - A computer or numerical model that uses the difference form of the differential equation governing groundwater flow in order to simulate groundwater conditions.

Flocculation - The agglomeration of fine suspended matter in water or wastewater following addition of coagulants and gentle stirring.

Forebay - The portion of an alluvial groundwater basin where the permeability of surficial deposits allows substantial groundwater recharge.

Groundwater basin - A hydrogeologic unit containing one large aquifer or several connected and interrelated aquifers.

Halogens - A chemical element such as chlorine, bromine, iodine, and fluorine, which forms salts by direct union with metals.

Hardness - A characteristic of water caused by the presence of constituents such as carbonate and magnesium which react adversely with soap and cause deposition of scales in fixtures.

Hydraulic conductivity - A constant, K, that serves as a measure of the permeability of a porous medium.

Lacustrine - Pertaining to a lake; lacustrine sediments were deposited in the bed of a lake.

Limnological - Pertaining to the study of lakes, including biological conditions.

Nitrates - A type of nitrogen compound sometimes occurring in water as a result of sewage disposal or fertilizer application, which in excessive amounts can cause methemoglobinemia, or blue-baby syndrome.

Ozonation - A water treatment process in which ozone is bubbled through water in order to destroy organic compounds, and improve taste and odor.

Perennial yield - The rate at which water can be withdrawn on a long-term basis under specified operating conditions without producing an undesired results such as groundwater depletion, degradation of water quality, development of excessive pumping lifts, land subsidence, or interference with water rights.

Pollution - The artificially induced degradation of natural water quality.

Porosity - The measure of the interstices or voids contained in rock or soil.

Potentiometric surface - An imaginary surface coinciding with hydrostatic pressure level of the water in a confined aquifer.

Reverse osmosis - A demineralization process involving diffusion of water through a semipermeable membrane.

Seawater intrusion - The process by which coastal saline water displaces or mixes with freshwater in an aquifer.

Sedimentation - The gravitational deposition of suspended matter carried by water or wastewater.

Specific capacity - A measure of the productivity of a well; namely, the well discharge divided by the drawdown in a pumping well.

Specific conductance - A measure of the electrical conductance of a groundwater sample, which indicates the total dissolved solids content. Also called electrical conductivity (EC).

State action levels - The concentration in water of a pollutant, set by the California Department of Health Services, which triggers state involvement in potential water quality problems.

Storage coefficient - The volume of water that an aquifer releases from or takes into storage per unit surface are of aquifer per unit change in the hydraulic head normal to the surface. Also called storativity.

Storativity - See storage coefficient.

Subsidence - Sinking of the land surface, in some cases as a result of extensive lowering of groundwater levels caused by heavy pumping from confined aquifers.

Trichlorethylene (TCE) - A volatile organic compound commonly used as a industrial degreaser or as a dry-cleaning solvent; a ubiquitous contaminant suspected to be a carcinogen.

Transmissivity - The rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient.

Trihalomethanes (THMs) - Chemical compounds formed by the reaction of halogens with organic matter in water. Chloroform, a THM and byproduct of water chlorination, is a suspected carcinogen.

Unconfined Aquifer - An aquifer in which water exists under atmospheric pressure; the upper water surface is the water table, which rises and falls in response to recharge and discharge.

Vadose Zone - The unsaturated zone existing from the ground surface down to the water table, where soil pores are occupied partly by water and partly by air.

Verification - The process of testing a computer model or hydrologic budget to determine its accuracy as a forecasting tool.

Volatile Organic Chemicals (VOCs) - A broad category of compounds that escape readily into air and generally flow easily in groundwater; defined largely by analytical laboratory techniques (gas chromatography), VOCs include solvents, gasoline additives, refrigerants, and other industrial chemicals. Many are suspected carcinogens.

Water table - The upper surface of the zone of saturation, and level at which water stands in a well tapping an unconfined aquifer.